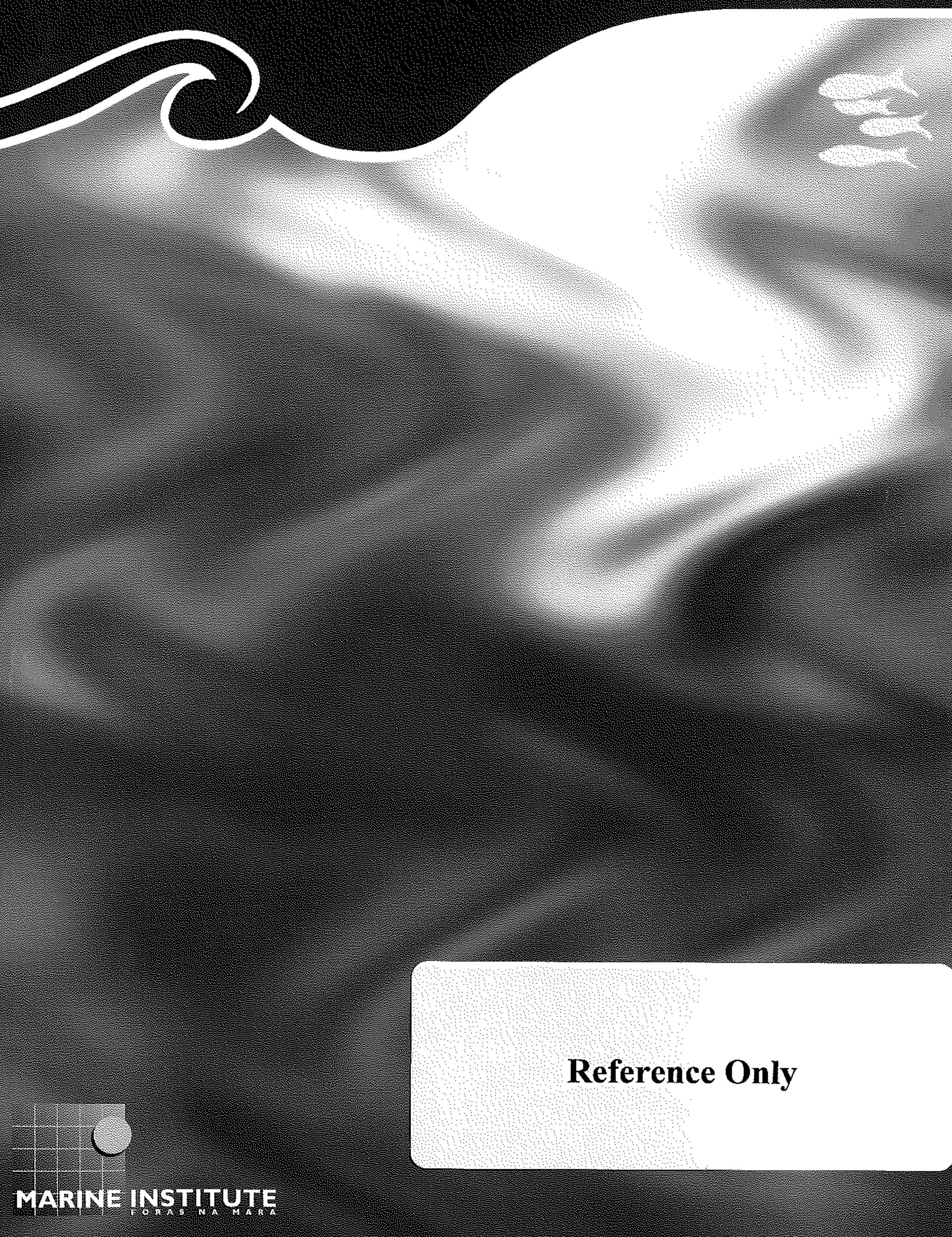
Management of the European Eel

edited by Christopher Moriarty and Willem Dekker



MARINE INSTITUTE
FORAS NA MARA

NO. 15 1997 FISHERIES BULLETIN

Management of the European Eel

Edited by

CHRISTOPHER MORIARTY[1] AND WILLEM DEKKER[2]

[1]Marine Institute, Fisheries Research Centre, Dublin 15, Ireland

[2]RIVO-DLO, PO Box 68, 1970 AB IJmuiden, The Netherlands

Second report of

EC Concerted Action AIR A94-1939

Enhancement of the European eel fishery and conservation of the species

CONTENTS

0. EXECUTIVE SUMMARY

0.1 Goal

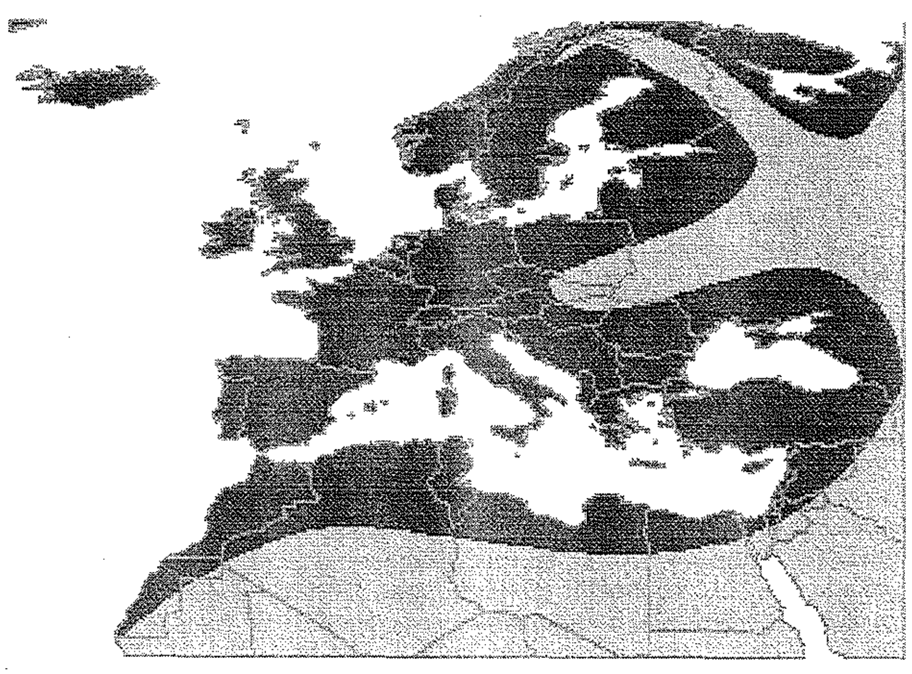
The goal of AIR Concerted Action A94-1939 *Enhancement of the European eel fishery and conservation of the species* is to develop a framework for the management of the European eel recognising its status as an international marine species with significant stocks in inland waters. The elements of the framework are:

- Assessment of current stocks
- Protection, rational exploitation and conservation of these stocks *and*
- Establishment of a permanent monitoring system.

0.2 Background

Concern expressed by fishermen, fish culturists and scientists alike on the decline in recruitment and fishery yields of the eel led to the establishment of a working group, EC Concerted Action AIR A94-1939, to pursue a project entitled *Enhancement of the European eel fishery and conservation of the species.* Scientists from ten countries have contributed to the current report and its predecessor, published in 1996. The reports present an account of the eel fishery tougher with scientific data of significance in control of the stocks and make recommendations for future management.

The European eel, *Anguilla anguilla,* is found and exploited in fresh, brackish and coastal waters in almost all of Europe (as well as in northern and western Africa). It reproduces in the open Atlantic Ocean. Therefore, it qualifies as a highly migratory marine species. The life cycle has still not been completely resolved, but all current evidence supports the view that recruiting eel to continental waters originate from a single spawning stock in the Atlantic Ocean, far outside the reaches of management responsibilities of the governments on the European continent.



On the continent, eel are distributed over virtually all water bodies, including rivers, still waters, estuaries and coastal areas. The continental distribution area is estimated at *ca.* 90,000 km^2 and the total production amounts to 30,000 t at 180 M ECU (plus 360 M ECU added value). An estimated 25,000 people in rural areas receive an income from eel fishing.

Fisheries for eel are found throughout the entire distribution area including large parts of Eastern Europe where young eel have been stocked. The target of the fisheries varies from glass eel freshly recruited from the ocean to female silver eel of 20 years old or more on their way back to the ocean. Nowhere is the eel fishing industry made up of units of a size appreciable at conventional international management levels. The fisheries are generally small-sized and scattered throughout Europe and must be largely considered artisanal.

The processing and trade industries are organised in companies of larger size and operate on international scales. Processing occurs both on local and centralised, regional scale, but trade is mostly confined to the continent. An exception is the newly recruited glass eel, which in recent years has been dispatched to eastern Asia to an extent which has given rise to serious concern as to the future viability of the eel industry as a whole within Europe.

Aquaculture takes place in southern and western Europe and ranges from extensive outdoor culture (Italy) to technically highly sophisticated indoor culture systems (mostly central and northern Europe). Total production amounts to 7,600 t. Whatever the system used, all aquaculture is dependent on wild-caught young eel, because attempts to induce artificial reproduction have failed at the young larval stage. The intensive aquaculture industry in eastern Asia (150,000 t production) is also based on wild-caught eel. Because of the shortage of young Japanese eel, substantial quantities of European glass eel are being purchased on the European market at excessive prices. Increasingly, the European users of the glass eel are out-competed.

Management, monitoring and fundamental research have been carried out at the national level, almost without co-ordination between the individual countries, as if we are dealing with local stocks. This is demonstrably not true and the need for international management has recently become apparent from continent-wide declines in recruitment, falling catches in large parts of the continent and shortage of seed material for stocking.

0.3 Comparison of eel with other fish species

There are fundamental differences in biology and our knowledge base between the eel and almost all other fish species to which international management systems are applied.

The most significant of these differences is that the full life cycle of the European eel has not yet been elucidated. In particular, little is known of what happens between maturing (silver) eel emigrating from freshwater and the subsequent return of glass eel to the coast. The location of the spawning grounds is only surmised from the appearance of larvae (leptocephali) in the plankton, and the spawning biology in the wild is completely unknown. Available genetic evidence supports the established view that there is a single spawning stock which breeds in the ocean, but this has never been observed.

Currently, full life cycle international management approaches are applied to other highly migratory fish species such as salmon. These comprise estimation of spawning stock, spawning stock to recruitment relationships, and post recruitment growth back to spawning stock. These cannot yet be used in any reliable way for eel, and are unlikely to be possible on the basis of existing knowledge.

However, better information is available on the freshwater growing phases, their habitat requirements and capability of sustaining exploitation. On the continent of Europe, eel distribution is widespread and, as a starting point from which to work toward a stock-wide approach in future, management of this scattered resource will benefit from international co-ordination, and integration of national practices into an international framework.

0.4 Proposed management action

0.4.1 Market control of glass eel

The development of a major export demand and consequent high prices for glass eel threaten the very existence of stocking programmes already in progress. Unless addressed as a matter of urgency, these factors are likely to prohibit any significant moves towards realising the full potential of European waters as a source of eel and could lead to an increasingly rapid decline of the capture fisheries for yellow and silver eel. Consideration at Commission level of ways and means of maintaining an adequate supply of glass eel for Europe should be given the highest priority.

0.4.2 Baseline survey and monitoring programme

The Concerted Action has compiled all available information of relevance on fisheries and biology and has concluded that this is far too fragmentary and incomplete for the requirements of fully effective management of the stocks. Implementation of one-off national surveys and of monitoring programmes co-ordinated on a pan-European basis are urgently required to inform management processes.

0.4.3 Distribution of stocking material

The Concerted Action has shown that sufficient glass eel are currently captured to provide the stocking material required not only to take the precautionary measure of increasing the spawning escapement but also to prevent further decline of the capture fishery and to restore or enhance it. Following the completion of the baseline survey advocated in 5.7.2, an international group, similar to the Concerted Action, should be convened to formulate a much more detailed series of recommendations for the rational use of the available stocking material.

0.4.4 Financial and employment implications

The Concerted Action calculated that the wild eel are produced from an area of *ca.* 90,000 km^2 and that only 3% of the habitat has been rendered inaccessible to eel by man-made barriers. Natural recruitment is equivalent to 67 t a^{-1} of glass eel; there is additional stocking of 33 t a^{-1}. The area is estimated to be understocked by 644 t a^{-1} of glass eel. If stocking were to be carried out at this rate, an additional yield of 60,000 t could be attained. Capture of this quantity would provide part-time employment for 40,000 people. As the Far Eastern eel culture production is 150,000 t and grows at a rate of more than 10% per annum, it is clear that demand continues to be extremely high and the prospects for sale of an increased yield of wild eel appear to be excellent.

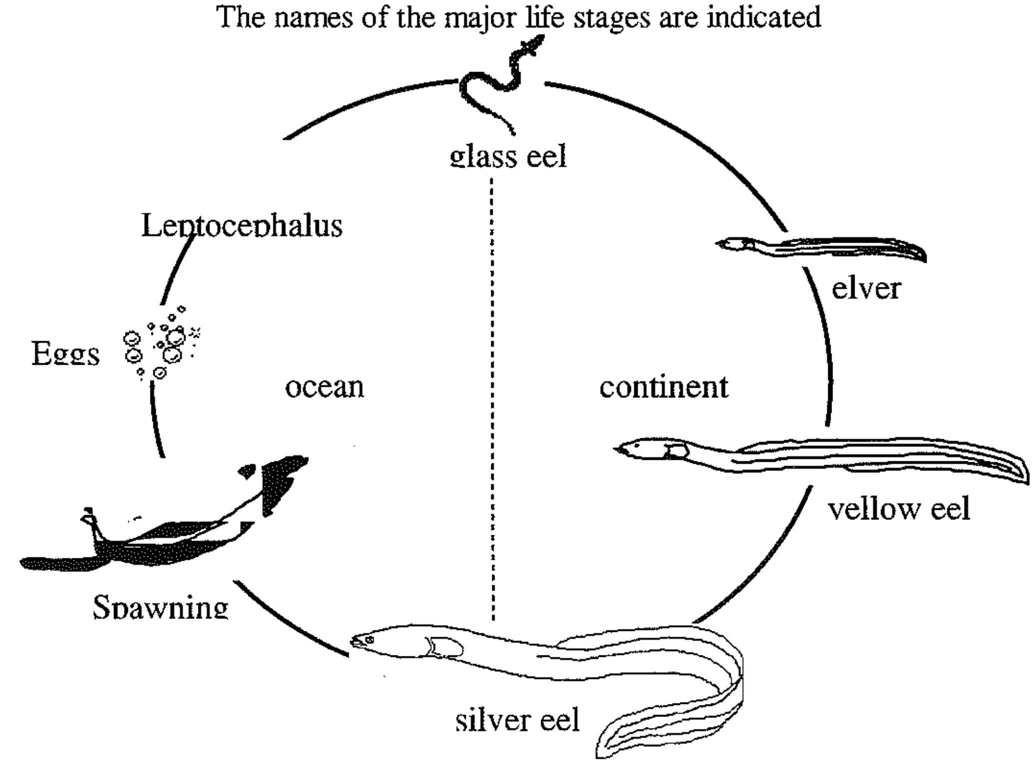
The annual cost of the glass eel required for stocking at current prices is 80 M ECU; the value of the yield to be expected from stocking is 360 M ECU.

0.5 Political implications

The Concerted Action has shown that sufficient stocking material exists to enable major development of the European eel fishery *while ensuring the conservation of the species.* Progress will be slow, involving a time lapse of 5 to 10 years before the effects of co-ordinated management will appear. Consideration of this matter is urgent because the fishery is at present in an alarming state of decline.

The life cycle of the European eel

The names of the major life stages are indicated



1. INTRODUCTION

1.1 Past working parties and research

Current international consideration of the European eel began at the 5th Session of the European Inland Fisheries Commission (EIFAC) held in Rome in 1968. EIFAC organised a Consultation on Eel Fishing Gear in Hamburg in 1970 and in 1976 EIFAC, jointly with the International Council for the Exploration of the Sea (ICES), held a symposium on eel in Helsinki. This clearly established the unique status of the eel as a target of important commercial fisheries, mostly located within national boundaries but dependent on a spawning stock in international waters.

The Helsinki conference led to the establishment of a Working Party on Eel which has remained in existence ever since, meeting in alternate years and stimulating dissemination of knowledge of the species. While recognising the need for co-operative research, the Working Parties were unable to pressurise member governments into providing the necessary support. In spite of these limitations, they published definitive international studies on tagging and on age determination.

The Working Parties also established a monitoring regime for recruitment and charted the dramatic decline of supply following a peak of abundance in the 1970s. A meeting of the ICES Working Group in 1991 concluded that, for biological reasons as well as lack of manpower, it was not possible to make an assessment of the eel stocks of Europe. Two years later, in 1993, the EIFAC Working Party prepared a statement on the future of the eel and its fisheries and compiled a list of research and monitoring requirements, with particular reference to the observed decline in recruitment.

In the following year, 1994, members of the Working Party decided that it was desirable and would now be possible to prepare a stock-wide management plan, based on existing knowledge. Such a plan would be based on available data on the fisheries and on management-related biology. It would be a preliminary document, in view of the sparsity of information, and would incorporate an outline of the research and monitoring work required to prepare a definitive strategy for the enhancement of the fishery and conservation of the species.

A proposal for a Concerted Action to collate the existing data and formulate the management plan was accepted by DG XIV of the European Union. Work within the Concerted Action began in February 1995.

1.2 First AIR report

The first report of the Concerted Action, published in 1996 (*Report 1*), confirmed that reliable data on eel fisheries are extremely scarce. Wide discrepancies were found between official fishery information and estimates arising from the many sources identified by group members.

Important conclusions were:

1.2.1 Quantity and value

The commercial yield from European eel fisheries is in the region of 22–30,000 t per year, with an estimated catch value to fishermen of about 180 M ECU to which a notional value of 360 M ECU must be added in view of the labour-intensive trading and processing element.

1.2.2 Manpower involved

Whilst relatively few people are engaged full time in eel fishing, considerable numbers are employed in highly specialised marketing and processing and not less than 25,000 part-time and casual fishermen gain a valuable supplementary income. In addition to the former group for whom the eel is a target species, *Report 1* identified coastal multi-species fisheries which could not be sustained in the absence of eel. The eel therefore makes a socio-economic contribution out of all proportion to the numbers of full-time eel fishermen, supplementing income from other fishing activities and from low-paid work, especially in communities where unemployment is high.

1.2.3 Decline of recruitment

Recruitment and catch of glass, yellow and silver eel have declined considerably since the late 1970s. This causes obvious financial problems for fishermen but, in addition, is reducing the supply of seedstock for restocking and aquaculture and the supply of the raw material to the lucrative processing industry.

1.2.4. Current management practice

Report 1 cites cases in which management practices have allowed maintenance or increase in catch in spite of the reduced natural recruitment.

The report confirmed the view that management techniques such as stocking, the use of passes and the exercise of controls on fisheries can be used to maintain or enhance sustainable yields, whilst helping to support the overall European stock. Further information was needed to clarify key issues to inform future cost-effective management options. Particularly important are data on natural stocks and yield in relation to fishery exploitation levels and other influences, such as loss or impairment of habitat utilisation due to barriers and pollution.

1.3 Review of biological data

Having prepared an assessment of the fishery in *Report 1*, the second phase of the Concerted Action sought to review all available biological data relevant to the formulation of management plans. Each of the participants was requested to prepare a review of the literature for their country under a standard set of headings. These reviews, revised in the light of discussion at the meeting of the group in Rennes in February 1997, are presented as Annex 1 of this report.

The exercise, while demonstrating with unwelcome clarity the paucity of such material, fulfilled two essential requirements for the Concerted Action. Firstly, it collated a wide range of information which may be extrapolated from isolated observations to form a continent-wide picture of the population biology of the eel. Secondly, it revealed the most important gaps in knowledge which may be filled by national or by international co-operative research in the future.

1.4 Overview of the report

Chapter 2 of this report provides a European overview of the material in the country reports. Based on this, Chapter 3 considers the potential for conservation and development and describes the management options. Chapter 4 presents the research and monitoring requirements for developing the management plan and determining its effectiveness. The final chapter summarises the management options and research requirements and puts forward recommendations for immediate and medium-term action.

This report draws heavily upon the information presented in the first report of the Concerted Action, as well as upon the country reports presented in Annex 1. Although only the combined chapters, together with the first report, provide a full, coherent view on the enhancement of the European eel fishery and conservation of the species, all individual chapters have been written as stand-alone texts. This objective necessitated some repetition in the text to which cross-references are given.

The Country Reports were prepared in the course of 1996 and early 1997. The Concerted Action held its second plenary meeting in Rennes, by courtesy of the Director of the Laboratoire Halieutique of ENSAR. At this, the Country Reports were studied and the first drafts of the overview chapters were prepared and agreed.

Chapters and sections were edited by individual participants to the Concerted Action, namely: Eleonora Ciccotti (Chapter 2, Section 3.1), Willem Dekker (Section 2.4, Section 3.4, Chapter 4, Annex 2), Brian Knights (Section 2.5, Chapter 3), Christopher Moriarty (Chapter 0, Chapter 1, Chapter 5), Robert Rosell (Section 0.3, Section 2.5, Annex 3). In addition to those named above, Eric Feunteun and Julian Reynolds took part in the final editorial meeting of the Concerted Action held in Dublin in April 1997. To them and to the colleagues listed in Annex 5, the Editors offer most hearty thanks for their enthusiasm and willing help.

2. EUROPEAN OVERVIEW OF THE COUNTRY REPORTS

The unique life cycle and biology of the eel, its ecological adaptability to a wide range of environmental conditions, and its consequent distribution over a wide range of different habitats has led to analytical research on an extensive range of topics in most countries. Research has tended, however, to be fragmentary and uncoordinated, making it difficult to draw useful indications for management, and the task of summarising information aimed at a common line of management seems particularly difficult. To obviate this, within the second phase of the Concerted Action, participants prepared a review of the information for each country as available from the literature, following standard headings useful for management. In this chapter, the relevant information has been integrated in order to obtain a continent-wide picture of the present status of eel stocks. Despite the scarcity of information on some aspects, a global overview of the distribution area and of habitat availability and quality has been obtained, as well as an overall picture of present levels of exploitation for the different life stages (glass eel, yellow eel and silver eel) and of the different management strategies carried out in Europe. Information has been obtained and estimates made, to provide guidelines for future management.

2.1 Habitat

In order to assess the eel stock and its present level of exploitation, an evaluation of total versus available surface area has been made for each country, and hence for the whole of Europe (Table 2.1). All habitats have been examined, both marine and inland, taking into account both their extent and their accessibility. Referring to the latter, a series of general considerations can be drawn not only regarding their *physical* accessibility, but also their suitability for eel with regard to environmental quality, which will be discussed further in Chapter 3. All habitats where eel can be found have been considered as potentially accessible to eel, without directly implying that all available surface is at present suitable for eel colonisation and for sustaining local stocks.

Table 2.1 Surface area (km^2) of eel habitats (summary of data from Annex 2)

	Accessible	Inaccessible		Total
		artificial	natural	
Fresh still	56	4	40	53,821
Fresh running	62	25	13	4,364
Saline closed	100			17,466
Saline open	100			21,046
Baltic	60		40	27,100
Total	87,335	3,211	33,252	123,798

2.1.1 Coastal waters, lagoons and estuaries

With regard to *coastal waters*, the Baltic Sea is the most significant portion of marine habitat supporting eel stocks, even if it has been compared to an estuary owing to its peculiar morphology. The total surface of the Baltic suitable as a marine habitat for eel is estimated as 16,135 km^2.

Sweden accounts for the largest portion of coastal waters available for eel, with 34,100 km^2 of surface. Of these, 8,600 km^2 lie on the Swedish west coast, with depths of less than 20 m and in which eel are abundant, and 25,500 km^2 constituting the northern part of the Baltic. Of the latter, only 14,600 km^2 are considered available, as eel fishing takes place there, even if with a decreasing population. The northern limit for eel distribution, or at least of eel fishery, in the Baltic nowadays is 60º. In Denmark the area of coastal waters supporting eel stocks is of the order of 10,000 km^2, embracing all the Danish coasts. Eel fishing also takes place along the entire Baltic coast of Germany (900 km^2).

Eel are also exploited in the North Sea, where the German portion amounts to 1,800 km^2, and in Dutch coastal waters, of which about 5,000 km^2 are available as eel habitat, fished as a by-catch of shrimp fishery. Eel stocks are also exploited in the southern North Sea; they are caught in the coastal waters of Great Britain as far as the English Channel. Eel are reported in by-catches on the Atlantic side of Great Britain, but no significant marine eel stocks have been located for Ireland. On the Atlantic coast of France, only a small part of the trawl fisheries is directed to eel. Sporadic occurrences have been reported in Atlantic coastal areas of Portugal and Spain, but mostly in sites subject to freshwater influence, while no marine-dwelling eel have been reported from the Mediterranean coasts of France, Spain, or Italy.

With regard to *brackish coastal habitats*, a distinction must be made between estuaries and habitats such as fjords, lagoons or brackish environments like the Waddensea. On the whole all these environments support relatively large eel stocks compared to open coastal waters. No true estuaries of any significance can be said to exist in Sweden, but there is an abundance of eel in open coastal waters. In Denmark, brackish environments, fjords, estuaries and lagoons cover 3,000 km^2, while Dutch brackish areas, corresponding to the terminal stretches of the rivers Rhine, Meuse and Schelde that flow through the Netherlands in an intertwining network of branchings towards the North Sea, amount at present to about 500 km^2, having been greatly reduced because of land reclamation. To these, 1,450 km^2 of the Waddensea must be added, whose waters are brackish owing to the flow of the Rhine to the North Sea through Lake IJsselmeer. Large brackish areas are present in Germany: the Elbe and Oste estuaries, Wyk/Föhr lagoon, Helgoland along the North Sea coast and Oder estuary, Oder lagoon and Coventer See lagoon along the Baltic coast.

About 2,800 km^2 of reclaimed marshes are present on the western Atlantic French coast and include 240 km^2 of water surface; there are about 50 km^2 of coastal lagoons on the Portuguese coast. The region richest in coastal lagoons is in the Mediterranean, with 350 km^2 of coastal lagoons in France, 171 km^2 in Spain and 1,500 km^2 in Italy. All these support large eel stocks, exploited by local fisheries. The potential production of these environments is very high (ranging between 20 and 40 kg ha^{-1}), but in most cases habitat quality has progressively deteriorated owing to human impacts (eutrophication following pollution, water and land management, etc.).

It is difficult to make an exact estimate of the extent of true estuarine areas, defined as lower river stretches under tidal influence, for all countries. A surface of 21 km^2 is reported for Bann and Foyle estuaries, the only significant ones in Northern Ireland; about 600 km^2 of estuarine surface can be estimated for the Irish Republic (the mouths of 237 rivers of which 16 are > 1 km^2 in extent) and about 5,000 km^2 in Great Britain (where 162 main rivers are present). All of these estuaries are believed to support eel stocks, but only a small number of them support known eel fisheries, more than 85% of the total being unexploited. Even in Atlantic estuaries (most of the 1,000 km^2 of French estuaries, the 325 km^2 of Portuguese coasts, most of the 60 Spanish rivers) and in the Mediterranean (Ebro, Jucar and Securo are the principal Spanish rivers discharging in the Mediterranean; about 36 estuaries along the Italian coasts) eel are probably present at all stages, but fishing for yellow and silver eel is confined to a very low number of them as, in most, glass eel fishing is practised preferentially.

In total, open saline habitats suitable for eel include the 16,135 km^2 of the Baltic plus over 21,000 km^2 inclusive of fjords, coastal waters and estuaries, while closed saline habitats (coastal lagoons, etc.) amount to over 17,460 km^2.

2.1.2 Freshwaters

The country with the largest surface of *still freshwater habitat* is Sweden, with 39,639 km^2 of lakes, of which 19,019 km^2, 48% of the total, are considered available for eel production. At the moment, about 11,074 km^2 are estimated to support eel stocks, but developed eel fisheries are carried out in only about 4,921 km^2. Rivers amount to about 792 km^2 in Sweden, supporting eel in most cases, but there are no directed fisheries at present except at artisanal fixed traps, whose catches are assumed to come from connected lakes. On the whole, the constraints that render 52% of still freshwater habitats and about 65% of running freshwaters inaccessible or unsuitable to eel are natural, mainly due to low temperatures and high altitude in northern Sweden. This is reflected in both low productivity and reduced recruitment. Man-made constraints such as physical obstacles to migrations are in most cases compensated for by eel passes or upstream transportation, even if in some areas these have fallen into disuse recently following lack of recruitment.

Danish lakes and reservoirs amount to 440 km^2, and there are 150 km^2 of river surface: all can support eel, although 10% of the Danish streams are contaminated by ochre and local stocks have been reduced. In the Netherlands most freshwater habitats (3,400 km^2 of rivers, canals, polders and lakes including the IJsselmeer) are accessible to eel.

In Germany about 25% of the habitat is inaccessible, owing mainly to man-made physical obstructions: 3,000 km^2 of inland waters are considered suitable for eel, while 1,820 km^2 of lakes and 480 km^2 of rivers are exploited by commercial fisheries. Ireland has 2,071 km^2 of lakes (1,445 in the Republic of Ireland, 626 in Northern Ireland) and 73 km^2 km^2 of rivers (53 km^2 and 20 km^2, respectively, in the Republic and Northern Ireland): all are considered suitable for eel, and inaccessible areas are limited to not more than 5%. The same can be said for Great Britain (1,924 km^2 of lakes and reservoirs and about 500 km^2 of rivers), where impassable obstructions are few and chemical obstructions absent. Major hydrodams are absent from England and Wales, and large tidal barriers are provided with passes. On the other hand weirs, sluices and other water regulation devices inhibit migration and recruitment, and restrict access to reservoirs.

In France still fresh waters, natural lakes, hydrodams, reservoirs and man-made ponds, amount to 1,696 km^2, plus 840 km^2 of rivers and canals. Most of this surface is suitable for eel, but man-made or natural obstacles account for 50% reduction of accessibility to lakes and 10% for riverine areas. Access by eel is seriously curtailed in many river systems by multipurpose dams, while in some rivers tidal barriers interfere with eel colonisation close to the mouths of estuaries, despite the presence of fish passes in some regions.

The highest rate of inaccessibility for freshwater habitats occurs in Portugal: the 266 km^2 of still freshwaters are almost entirely reservoir areas (natural lakes being limited to some small high altitude lakes), and of this surface 99% is considered inaccessible. Of the 60 km^2 of river surface, 70% is inaccessible because of dams. In most cases passes, where present, are ineffective.

A similar situation is found in Spain, where most natural lakes (total area 10 km^2) are at high altitude in the Asturias region, and therefore not suitable for eel. Rivers cover about 720 km^2, but most of the hydrographic system (93%) is considered inaccessible because of chemical pollution and physical obstructions.

In Italy, lakes and man-made basins total about 2,360 km^2 with about 108 km^2 of rivers and canals. Most of these can be considered suitable for eel, but colonisation is hampered by physical obstructions, dams reducing access both to upper stretches of at least 50 rivers and to about 60% of lakes.

2.2 Glass eel fishing and monitoring

In Sweden fishing for glass eel is allowed only for restocking or transfer within single river systems, and traps are used. In many cases, recruits consist also of elver and larger eel (15 cm and more). Catch data for six river systems provide historic data series for monitoring recruitment to Swedish coasts dating back as far as 1900. All data series indicate fluctuating patterns even in the past (before 1950), and a steady decline from several tonnes per year to a few kg in recent years. Total recruitment to the Swedish west coast has been estimated to be 5 million to 25 million of 0^+ recruits. Recently a total of 50 million elver on both coasts of the Sound has been estimated.

In Denmark, glass eel fisheries took place till 1990 on the west coast of Jutland (Vidå sluice), and catch records are available for the period 1968–1990, the highest having been recorded in 1968 and lowest in 1989 and 1990. Fishing has therefore ceased completely in Denmark, and recruitment failure is made up for by restockings performed with cultured eel 2–5 g (between 1 and 9 million stocked annually since 1987).

In the Netherlands, capture or possession of glass eel is forbidden, but glass eel fisheries on behalf of the Organisation for Improvement of Inland Fisheries (OVB) are allowed for restocking, amounting up to the 1980s to 3 t at one entrance to Lake IJsselmeer. Since then, owing to the recruitment decline, the actual catches fell below this quota, resulting in an extension of the fishery to catch 3 t at six sites along the coast (500 kg each), including a second inlet to the IJsselmeer. From 1995, a total catch of 5% of the total recruitment to the IJsselmeer has been allowed, since a fixed quota would have implied a greater impact on the declined recruitment. Problems have arisen in estimating the total immigration (158 t according to fishermen and 5 t according to the national fishery research institute, RIVO, corresponding to quota of 8 and 0.2 t, respectively).

Glass eel capture in Germany requires special permission, but glass eel and bootlace eel from fisheries are used for restocking. At present there is still one site where a glass eel fishery is carried out, on the River Ems at Hebrum. Data confirm a decline from > 4 t in 1974 to > 3 t in 1980, falling sharply to about 10 kg from 1983. Reduced recruitment has been ameliorated with stockings of imported glass eel from France and, since 1989, with pregrown elver.

In Northern Ireland a glass eel fishery takes place only at the tidal limit of the Bann, where ladder traps collect ascending elver to be transported to Lough Neagh. Thus, stocking data to Lough Neagh provide a monitoring series of recruitment, showing higher catches between 1965 and 1978 (average 6.1 t) and falling to an average of 2.1 t per season from 1979 to 1995.

In the Republic of Ireland capture or possession of glass eel for sale or consumption is forbidden. Glass eel fisheries in the Shannon, Erne and four other rivers supply material for intra-catchment stockings. On the Shannon, high catches were recorded, from 2 to 7 t, between 1979 and 1982, while in the following years annual catch has never been higher than 1.6 t. The trend observed on the Erne is not so definite, neither showing large catches in the 1970s nor declines since then, highest catches (4 t) having been recorded in 1982 and 1994.

In Great Britain, commercial glass eel fisheries began in the Severn in the 1940s, and extended in the 1970s to other rivers following increase in demand from aquaculture and for restocking. No regular monitoring seems to be carried out, and catch–return data are of poor quality, but export figures provide indications of diminished recruitment from the 1970s to 1980s (about 40–50 t) to recent years (20 t), while increase in demand has led to increased fishing pressure, encouraging fisheries in other rivers.

France is without doubt the leading country with regard to glass eel exploitation, organised commercial fisheries being present in most estuaries of the Atlantic coast, while glass eel fishing is prohibited on the Mediterranean. The major glass eel fisheries are in the Loire, Vilaine, Gironde and Adour, with a total of over 28 exploited estuaries. Fishing activity began to develop consistently from the 1960s in connection with the increase in demand from the Spanish direct consumption market. Since the 1980s, professional fishermen have progressively organised a regulation system, to increase efficiencies and to prevent overexploitation. The official statistics do not seem reliable at national level, although a scheme based on a logbook system filled in by the fishermen and conveyed to a national database has been set up. Many surveys have been conducted at regional scale, integrated with scientific work, providing useful indexes that allow quantification of recruitment trends in estuaries such as the Vilaine, Loire and Gironde.

In all French estuaries a decline in recruitment has been observed from the 1980s. Official statistics confirm the fall in glass eel runs, total production having reduced from the 1,345 t estimated in 1970 (fishermen having been estimated as 648 marine and 2,424 riverine professional fishermen) to 500 t (850 marine fishermen and about 4,000 riverine, the latter including land-based professional and amateur fishermen) in 1986. About 578 t of glass eel were caught in 1995 according to the French maritime authority. The general trend is a marked decrease in fishery yields despite an increasing fishing effort.

In Portugal glass eel catches are permitted only in areas under tidal influence. The main fishery is on the estuary of the River Minho, where hamen nets are used, while in other Portuguese estuaries only dip nets from river banks are allowed. Data from commercial catches on the Minho provide for monitoring of recruitment to Portuguese coasts, indicating a fall from more than 20 t in the period 1976–1984 to 14 t in 1986 to 8 t in 1988, and to 5 t in recent years. Official statistics seem to be underestimates, and a certain number of non-professional fishermen are present.

Spain has up to now been the main glass eel consumer in Europe. Glass eel fisheries are therefore well developed, carried out both on the Atlantic coast (at least 12 estuaries in Asturias, all estuaries of northern coasts from Galicia to Basque region and Guadalquivir estuary in the South) and on the Mediterranean (Ebro Delta and inlet channels to lagoons). On the whole, estimates indicate production averaging 150 t for the Atlantic coasts and 50 t for the Mediterranean. Reliable catch data are available for the Nalon in Asturias, dating back to 1952. Catches from 1952 to 1972 were between 10 and 20 t, increasing noticeably in the 1970s and reaching 60 t in 1977. Since then, in the 1980s they returned to previous levels, falling in the 1990s to a minimum of 6 t in 1995–1996.

In Italy, glass eel exploitation dates back as far as the 17th century, natural recruitment representing the basis of the *vallicultura* of Northern Adriatic lagoons. Glass eel fishing has been performed on a professional basis since the 1960s and 1970s, following the increased demand from the aquaculture sector and in consequence of the reduced spontaneous ascent in coastal lagoons owing to modifications of the ecological conditions of these environments. Besides the northern Adriatic (Po Delta), the glass eel fishery is carried out mainly in the Tyrrhenian regions (coast of Tuscany, Latium and Campania). Glass eel fishing is forbidden except for those fishermen who have obtained special permission. Official statistics appear unreliable, and do not allow exact quantification of the total yield, which can be roughly estimated as ranging between 4 and 6 t per year. A marked decrease in recruitment has certainly taken place, indicated by the decrease in authorisation request, as the glass eel fishery is no longer profitable despite the increase in prices. Monitoring is carried out on a regular basis only in the Tiber estuary, where historical data are available. Besides a fluctuating trend in yields, an overall decreasing trend has been recorded, catches falling from > 6 t per season in the period 1975–1980 to about 4 t per season in the following years to a minimum of less than 200 kg in 1995–1996.

Throughout Europe, glass eel fisheries are carried out in more than 90 estuaries, but their characteristics can be said to differ greatly within and between countries, ranging from the ladder- and trap-based fisheries of countries such as Sweden or Ireland, aimed at stocking river systems, to the intensive fishery carried out on the French Atlantic coasts. Some of the sites mentioned above are included in a monitoring network of recruitment at the European scale, carried out within the Joint EIFAC–ICES Working Party on Eel. Despite the differences in survey methods (catch data based on different fishing techniques, glass eel numbers recorded at ascending ladders, experimental fishing), all point to a strong reduction in eel recruitment to European coasts.

2.3 Yellow and silver eel stocks

Information from the Country reports indicates an extremely variable situation in some qualitative aspects of eel stocks such as growth and population dynamics, as well as to parasitism, contamination and pathology. With reference to the latter group, information is scarce and scattered, routine monitoring being limited to a few examples. The former features are strongly related to local habitat conditions, including latitude/temperature, productivity and exploitation levels. Southern countries report decreases in size of yellow eel, attributed to growth overfishing and decline in silver eel catch has been observed in Lough Neagh, Northern Ireland. Shifts in sex ratios have been observed in environments such as Mediterranean coastal lagoons.

Examples of eel yields are given in Table 2.2. *Report 1* had indicated the inconsistency of national catches as quoted by official statistics, but further research by country representatives shows declines in yellow and silver catches from all countries in which fishing for these stages takes place, and some fisheries have collapsed. The only exceptions are local populations, sustained by restocking.

Eel fisheries statistics relating to the Swedish part of the Baltic show that catches in the 26 year period 1940–1965 amounted to 1,731 t but these have fallen to 631.6 ± 126.5 t in the 14 year period 1980–1993.

Table 2.2 Examples of data showing major changes in stocks and fisheries

	Habitat	Category	Period	Unit	Quantity
Sweden	Baltic	Commercial catch	1940-65 - 1980-93	t	1,731 - 632
Denmark	Limfjord	Commercial catch	1900s - 1994	t	800 - 10
	Limfjord	Bottom trawl	1980 - 1994	CPUE	14 - 1
Netherlands	River Rhine	Fishing effort	1920s - 1990s	no. boats	500 - 10
	IJsselmeer	Eel yield	1940s - 1990s	kg / ha	> 5 - 1
N. Ireland	Lough Neagh	Silver eel catch	1965 - 1995	t	330 - 138
	Lough Neagh	Yellow eel catch	1965 - 1995	t	236 - 659
Italy	Comacchio l.	Eel yield	1974-76 - 1990s	kg / ha	> 19 - < 5
	Sardinian lagoon	Eel yield	1957-64 - 1970s	kg / ha	120 - 40
	Coastal lagoons	Total production	1986 - 1995	t	2,000 - 700
	Lakes / reservoirs	Total production	1989 - 1993	t	376 - 308
France	Brittany rivers	Average biomass	1990 - 1996	kg / ha	70 - 40
Atlantic	Normandy rivers	Average biomass	1990 - 1996	kg / ha	120 - 60
Mediterranean	lagoons	Total production	1991 - 1994	t	1,264 - 251
Mediterranean	B. Sigean lagoon	Eel yield	1991 - 1994	kg / ha	99 - 45

In Denmark all available data show a decreasing yield. In the Limfjord, eel fishing is traditionally very important, but catches have decreased considerably. At the beginning of the 20th century catches averaged 800–900 t but began to decline in the mid-1950s and in 1994 amounted to only 10 t. A bottom trawl survey in the Limfjord showed a decrease from 14 eel per unit effort (30 min trawl) in 1980 to only 1 eel during 1986–1990. In Ringkøbing Fjord catches are said to have been reduced by 90% from the 1960s to the 1990s and the official catch for the whole country showed a reduction of about one-third over the same period.

In the Netherlands, catches have declined over several decades. Following the recruitment failure in the 1980s, yield has fallen rapidly and only the last remnants of former fisheries exist. In historic times, more than 500 boats (*schokkers*) fished for eel on the river Rhine between Basel and the North Sea. Nowadays, the numbers have been reduced to less than 10 within the Netherlands, and none in Germany. Catches are not centrally recorded, but certainly do not exceed a few tonnes per boat.

Professionalisation of the fishery sector in the Netherlands since the Second World War resulted in about 400 mostly full-time fishermen in polders, canals and smaller lakes. In the decade 1985–1995 the number fell to below 300, with an average annual catch of 1 or 2 t per crew.

The long-term decline in the Dutch fishery has been caused mainly by reductions in the accessible area, through land reclamation, better drainage systems preventing upstream migration, eutrophication and pollution, but also by the profitability of fishery declining relative to rising average incomes, and recently through shortage of elver supply. In the IJsselmeer, the yield of silver eel has consequently decreased from 20% to less than 5% of the yellow eel catch, while the annual catch of yellow eel itself has dropped from over 5 to 1 kg h a^{-1}. Data on natural recruitment from the Waddensea and stock surveys on the lake itself, where no man-made stockings are carried out, correlate well over the years, both showing a sharp decline since the 1980s.

For Germany, CPUE data are available from the River Elbe over a 20 year period. Since 1980 a sharp decrease in the number of small eel has been observed. Similar results are reported for the River Weser. CPUE data for Lake Constance over a very long series of years showed an extremely low yield at the end the 19th century (in 1880 it amounted to about 0.001 h a^{-1}). This was noticeably increased by means of restocking with glass eel, begun in the 1950s with about 1.3 glass eel h a^{-1}, rising to 3.2 in the 1960s and to 13.1 in the 1970s. Yield increased to 5 kg h a^{-1} during 1980–1982.

No information is available for Great Britain, apart from a general impression of a decrease in the number of fisheries. Records of the numbers of silver eel traps in the Thames prior to 1086 and up to 1900 suggest that stocks in the upper waters of the catchment were very much greater than today.

In the Republic of Ireland a substantial increase in silver eel catch in the River Shannon began to be observed in 1979, 20 years after the initiation of a stocking programme, and the numbers of eel per unit effort in experimental fyke nets increased between 1969 and 1981, following which the sampling results suggested that a steady-state population had been attained. The mean annual silver eel catch at Killaloe, the principal fishery, from 1979 to 1988 was 27 t, against 18 t for the previous decade.

In Northern Ireland, mean annual declared catch of all eel from 1986 to 1995 was 730 t, range 650 t to 830 t. From 1962 to 1996, the Lough Neagh data, which account for 95% of the total, showed a declining trend with a shift from silver to yellow eel harvest as the bulk of the total output.

No data are available for Portugal nor for Spain, though for the latter there is a general impression that eel has become less plentiful in most rivers owing to dam construction and to pollution.

In Italy eel production is believed to have strongly declined, both in inland waters and in coastal lagoons. In rivers, eel populations have been reduced owing to the presence of numerous dams, most of which have inadequate fishways or none at all and are therefore impassable. Recruitment to most lakes has been considerably reduced by the construction of dams along the effluent rivers. However, eel yields have increased owing to increases in restocking in lakes such as L. Garda and Bracciano, carried out both to enhance stocks and to sustain local fisheries.

No extensive data are available for Italian fisheries in riverine environments, except for the River Tiber in the Latium region. Historical data series of glass eel catches have shown an overall decreasing trend, with catches dropping from over 6 t per season in the period 1975–1980 to less than 200 kg in the season 1995–1996. In spite of this, the total yield of yellow and silver did not show a dramatic decline; average production was of the order of 10–15 t per season, reasonably constant from year to year. This was, however, related to increasing fishing effort, from 200–300 fyke nets per day to over 600 in the 1990s.

Eel production in the coastal lagoons in Italy has strongly declined between 1975 and 1995. A typical case is that of the Valli di Comacchio, a complex of coastal lagoons in the Northern Adriatic, where traditional fishery management, vallicultura, has been carried out for centuries. Official data of fish production have been available since 1781. The trend in those 2 centuries has always been characterised by fluctuations ranging from 6 to > 30 kg h a^{-1}, attributable to such environmental problems as hypersalinity and freezing of the valli. The average annual yield of eel per hectare was 14.3 kg , about 78% of the total fish production. Higher yields were obtained after 1964, coinciding with restocking and seeding practices while, from the late 1970s, production has been considerably lower (5–7 kg h a^{-1}), attributed to falling recruitment in the Comacchio lagoons.

Similar falls in eel production in coastal lagoons took place between the 1970s and 1980s in the whole north Adriatic area and also in other regions. For example, in the Tortolì lagoon, in Sardinia, eel represented about 30% of total catches with a yield of 120–130 kg h a^{-1} in the period 1957–1964, but dropped to an average of about 40 kg h a^{-1} from 1965.

Similar declines have been observed in French Mediterranean coastal lagoons, such as Palavas (Languedoc) and Bages Sigean (Roussillon) lagoons. Yields and CPUE have decreased by about 40% since 1985, from 99 to 45 kg h a^{-1}. Total yields, estimated by the Maritime Statistics System, indicate a fall in yield from 1,264 t in 1991 to 251 t in 1994. Yields from reclaimed marshes on the Atlantic coast have also declined dramatically, from 37 kg h a^{-1} in the 1980s to the present figure of 10 kg ha^{-1}.

Data from inland waters in France are limited but a catch of 320 t, of which 120 t were silver eel, was reported for 1989. Total yield ranged between 75 and 100 t in the Loire, with 450 fishermen and between 10 t and 20 t in Vilaine, with fewer than 20 fishermen. Calculated biomasses fell from 70 to 40 kg ha^{-1} in Brittany and from 120 to 60 in Normandy.

2.4 Spawning stock and silver eel fisheries

In this section, the relationship between the silver eel fisheries and the spawning process is described.

2.4.1 Life stages

The continental eel stocks are made up of several, quite distinct life stages. It is essential to note that these stages taken together represent only the juvenile life stage of the species: larval stages and maturing/spawning stages are only to be found in the ocean. Silver eel, emigrating towards the ocean, have only just begun to mature. Although the morphological, physiological and behavioural changes are distinct, silver eel should still be qualified as pre-mature fish. Thus, unlike fisheries on most other exploited species, eel fisheries represent pre-recruit fisheries. Although spawning has not been observed in the wild, it is highly unlikely that eel survive after having spawned.

2.4.2 Silver eel fisheries

Silver eel fisheries are found throughout the distribution area of the species. Although statistical data seldom discriminate between yellow and silver eel landings and although the fishing industry often uses the same catching devices for both yellow and silver eel, the emergent picture is undoubtedly that silver eel relatively dominate the catch in northerly countries, while yellow eel dominate in southerly countries (see also *Report 1*).

The fisheries specific to silver eel all take place during their migratory season. Without exception, passive gears are set across the migratory route. In most cases, these gears are set in the opening of inland water systems towards the sea, or higher up in streams leading towards the sea. The speed of migration has not been quantified, but it appears that escaping silver eel reach the sea from the place where fishing takes place within a few days. Although fisheries exist in estuaries and the open sea (trawling), catches of silver eel beyond the river mouths are quite rare.

The Baltic fisheries are a notable and large-scale exception to this general view: silver eel are caught in rivers, on their migration towards the ocean but escaping animals are caught all along the coast and in the pound net fisheries in the entrances to the Baltic. Mark–recapture studies (Ask and Erichsen, 1976; Sers et al., 1993) have shown that high percentages of animals released at the coastal fishery sites enter the fishery again on their outward migration. Up to 70% of marked eel were recaptured, implying that 30% escape the fishery. From this percentage, a quantitative estimate of the amount of silver eel escaping the Baltic area was derived (Section 2.4.3, Annex 2).

In the Mediterranean, silver eel, derived from wild populations, are caught in coastal areas. The extensive aquaculture systems in Italy (North Adriatic valli and other lagoon fisheries) probably have a very high efficiency in exploiting their silver eel production. However, quantitative data are absent.

2.4.3 Spawner escapement

The efficiency of silver eel catching devices has been quantified in only a few cases. Mark recapture studies in the Baltic have been described in the previous paragraph. Additional evidence of the low efficiency of silver eel fisheries come from sites where separate fisheries are operating in series down a river system. For instance at Toomebridge on the river Bann (N. Ireland), catches in the lower of two weirs can form up to 40% of the total, implying an efficiency of less than 60% (R. Rosell, pers. comm.).

Mortalities of silver eel caused by passage through hydroelectric power stations have been quantified at several sites in Europe. However, there is currently insufficient basis for a quantitative assessment of the impact of these local mortalities on the contribution to the continent-wide spawner escapement. The approach taken in this report is to build upon the quantities of silver eel known to have passed all such obstacles and which have a free way out to the ocean.

In Table 2.3, the calculation of the minimal quantity of silver eel escaping from fisheries is presented. It is assumed, that all silver eel fisheries have a minimal escape rate of at least 10%. On the basis of reported quantities of silver eel caught, the accompanying amount of escapees was computed. The total escapement in Europe is estimated at 595 t minimum, equivalent to an order of magnitude of a million escapees.

The behaviour of silver eel in the Baltic and on the continental shelf has been studied by means of ultrasonic and radio transmitter tags. Amongst details on diurnal activity patterns and swimming depths, the main results indicate a rapid migration towards deeper waters. The tagging studies in the Baltic by Westin (1990) have hinted at the possibility that silver eel developed from glass eel transported from long distances may have difficulties in finding their way to the ocean. No tracking has been successfully operated beyond the continental shelf.

Table 2.3 Minimal estimate of silver eel escaping

	Surface area km^2	Yield t	Escapement % of yield
Fresh still	29,971	301	12
Fresh running	2,717	250	10
Saline closed	17,466	300	12
Saline open	21,046		10
Baltic	16,135	1,078	30
Total	87,335	1,929	595

2.4.4 Maturation

Maturing eel have never been observed in the wild. Experimental maturation has succeeded in producing eggs and larvae, but survival time of the larvae has been restricted to a couple of weeks. The relevance of the knowledge acquired from these experiments to the management of the wild stocks is only limited. Artificial propagation of eel for use in aquaculture or outdoor stocking is not a viable option in the foreseeable future.

2.4.5 Conclusion

In conclusion, silver eel represent a pre-mature life stage, but it is the last one which has been observed within its natural setting, known only from cross-sectional observations of rapidly migrating animals. Silver eel fisheries predominate in northerly countries, but capture efficiencies are generally low.

2.5 Current management practices

This section summarises standard management and regulation options available to eel fishery managers, marking those used or legislated for in the countries contributing to this report. Regional variations in approaches and tradition are marked, leading to corresponding selection of different sets of options due to the differing perceived importance of fisheries for the various stages of the life cycle.

2.5.1 Regional variation in management practice

The use of various options to manage glass, yellow and silver eel fisheries by participant countries is summarised in Table 2.4. There are strong regional differences in the way eel fishing and consumption traditions have led to current management practice, between the northern countries (including Sweden, Denmark, Germany, Great Britain and Ireland), with traditions of fishing for and consuming only yellow and silver eel, and southern countries (Spain and Portugal) with limited traditional interest in yellow and silver eel but strong traditions of direct consumption of glass eel as a luxury food. France and Italy fall between these two groups, with interests in yellow, silver, and glass eel fishing (the latter for aquaculture and stocking in both countries and in addition for consumption in France).

2.5.2 Measures to protect growing phases

Those countries without direct consumption of glass eel have tended to adopt management controls based on maximising recruitment to the growing stages, including measures such as banning glass eel fishing or permitting this only under licence for restocking purposes, provision, in some cases by legislative requirement, of elver passes or ladders on weirs or dams, and mesh size restrictions on gear such as fyke nets. The latter measure is sometimes reinforced by a corresponding minimum takeable size matching the likely escapement through a particular minimum mesh size (e.g. Ireland, Sweden, Denmark, the Netherlands and Italy).

Table 2.4 Conservation measures

	Glass eel and elver fisheries					Yellow and silver eel fisheries						
	Ban on commercial fishing	Use of elver passes	Gear control	Close seasons	Fishing/ dealing licences	Mesh size control	Other gear control	Close seasons	Fishing/ dealing licences	Size limits	Free gaps in weirs	Quotas
Sweden	*	*					*	*		*	*	
Denmark	*	*				*	*	*		*	*	
Germany	*						*		*			
Ireland (N)	*					*	*	*	*	*	*	*
Ireland(R)	*	*				*	*	*	*	*	*	
Great Britain		*	*		*	*	*		*			
Netherlands	*	*				*	*	*	*	*		
France		*	*	*	*		*	*	*			
Portugal			*	*	*		*	*				
Spain			*	*	*		*	*				
Italy					*	*	*		*	*		

2.5.3 Specificity of certain regulations to eel fishing

A number of countries adopt legal close seasons for yellow and silver eel fishing, but in some cases (e.g. Ireland) this simply reflects the traditional or practicable fishing seasons and may not be a true stock conservation measure, or is derived from a requirement to allow the unhindered migration of salmonids (e.g. Denmark, Northern Ireland, Republic of Ireland). Similarly, the legislative provision for free gaps in rivers exploited for yellow and silver eel in these countries is in essence a salmonid fish protection measure, which also serves to protect escapement of migrating eel. True season restrictions aimed at eel fisheries do exist, for example in Portugal, where the R. Minho stow net fishing is only permitted from November to April, with only hand dip net fishing for the remainder of the year. Also in Portugal, the use of fyke nets is only permitted in September and October, with only long line fishing permitted year round.

2.5.4 *Licensing*

All countries require both yellow, silver and glass eel fishermen to take out a licence to fish commercially, and some countries or regions add a requirement for compulsory catch returns for each licence. No country gives complete freedom on methods of fishing, and all restrict gear used in some way, restrictions often reflecting traditional local designs. In Italy, the grant of fishing licences by administrations can require a quota of catch for restocking purposes.

2.5.5 *Countries concentrating on glass eel fishing*

In France, Portugal and Spain and in the Bristol Channel/Severn Estuary in England, where there are extensive glass eel fisheries, the type of gear allowed is regulated in almost all cases, reflecting the way the local fisheries have developed different gear types. Examples include the standard elver net diameters of 1.2 m enforced in some French estuarine fisheries, and standardised stow nets in the R. Minho. In Italy, there is a complete prohibition on catching glass eel for direct human consumption, despite some local traditions of direct consumption.

2.5.6 *Stocking of growing phase eel fisheries*

Currently, stocking is carried out in some countries where the fishery emphasis is on exploitation of the growing phase or of silver eel, even though this practice is restricted, currently more than ever before, by the high price of glass eel and elver. In Ireland, glass eel harvested at tidal limits or obstructions in a number of river systems are moved upstream to support inland yellow and, subsequent, silver eel fisheries. In Sweden stocking, including some cases with relatively large growing eel, is carried out where stocks are available to restore, support and enhance fisheries, but in recent years limited supply and high cost have been problems. Denmark has a countrywide stocking programme using elver, to restore the fisheries. Glass eel stocking is also carried in the Netherlands, this being the only reason for some licensed glass eel fishing. Italian wild fisheries and *vallicultura* operations have traditionally been extensively stocked with both glass and bootlace eel, by public and private operators, to enhance stocks and to sustain fisheries. These operations continue where stocks are available, but the practice of stocking coastal lagoons is becoming less common due to environmental quality problems.

2.5.7 *Conclusions*

This section has summarised standard management and regulation. Regional variations in approaches and tradition are marked, leading to the corresponding selection of different sets of options due to the differing perceived importance of fisheries for the various stages of the life cycle. Other than official licences being required of almost all fishermen, there is little consistency in management practice, enforcement and controls across Europe as a whole, measures adopted by different countries having evolved to match their own particular fishery traditions.

3. FUTURE MANAGEMENT

Having reviewed the current distributions of stocks in different types of habitat throughout Europe, especially in relation to recruitment and accessibility, this chapter will discuss the implications of the data. Relationships to potential production, declines in recruitment and population dynamics are particularly important. These aspects are discussed in the context of management and the means of achieving such aims, and the needs for research and management (Chapter 4), leading to management planning (Chapter 5).

3.1 Habitat and potential eel productions

The European overview shows that eel can be found in all possible habitats, ranging from coastal marine waters to upper stretches of rivers, exceptions being mostly attributable to high latitude or altitude and to impassable barriers.

Constraints to the further extension of eel stocks seem to lie mainly in accessibility, at least if short-term effects are to be considered. Habitat quality (eutrophication, pollution, etc.) seems less influential, even if it may have a long-term effect through food quality and availability, diseases, genotoxic effects, etc. on stocks, affecting growth rates, survival and hence reproductive success. Comparison of current yields of yellow and silver eel fisheries with potential yields of outdoor waters, averaged for each habitat on the basis of information reported from each country, permits evaluation of the present level of underexploitation, and some theoretical figures of potential eel production in Europe (Table 3.1). In these calculations, only the presently accessible surface for each habitat in the represented countries has been considered. Figures on current yield in Table 3.1 do not include glass eel catches and aquaculture production of yellow and silver eel (in contrast to the reported figures in *Report 1*) and cover only the EU countries.

Table 3.1 Potential and current yield in yellow and silver eel fisheries (summary of data from Annex 2)

	Surface area (km^2)	Potential yield kg ha^{-1}	t	Known yield t	Under-exploitation t
Fresh still	29,971	10	29,104	3,340	25,764
Fresh running	2,717	11	2,867	715	2,152
Saline closed	17,466	14	23,962	3,002	20,960
Saline open	21,046	2	4,293	862	3,431
Baltic	16,135	5	8,068	1,325	6,743
Total	**87,335**	**782**	**68,294**	**9,244**	**59,050**

Marine or brackish habitats are accessible to eel and in most of them eel are present; this means that over 54,000 km^2 of habitat are available to eel. Most of the present yield comes from northern countries, in particular from the Baltic Sea and from fjords and brackish areas of Denmark, the Netherlands and Germany. These habitats are exploited to a high level at present. In some of them, for example in Denmark, eel production is sustained by stocking. On the other hand, fisheries for yellow and silver eel are present only in a few estuarine areas.

Overall, if an average potential yield of 2 kg ha^{-1} is assumed for coastal marine environments, and of 5 kg ha^{-1} for the Baltic, only 20% of the potential yield is obtained at present.

Mediterranean coastal lagoons form a special case, with high natural productivity but with yields falling in recent years to minimum levels. Environmental problems are often present in transitional environments such as lagoons and estuaries, mainly pollution and eutrophication, and these can affect both potential yields and escapement rates. Integrated management strategies are at present sought for most lagoons, for example in Italy, integrating aquaculture and fisheries with land restoration, tourism, etc.

The enhancement of potential eel yield in open coastal habitats would have the effect of contributing further to broodstock escapement. About 462 t can be estimated to escape from the Baltic, if an escape rate of 30% is assumed. By extrapolation, it appears that silver eel escapement from open marine habitat, most of which is unexploited, forms a considerable proportion of the total. In the major portions of open habitats, i.e. coastal waters and estuaries, the escape rate can be assumed to be high compared to that of closed saline systems where management strategies and fishing pressure reduce it considerably (to <10%).

Freshwater habitats amount to more than 32,600 km^2 accessible to eel, because at present about 40% of the total freshwater resource is either not accessible or not suitable, partly because of natural constraints such as high altitude, but chiefly because of man-made causes, mainly relating to physical obstructions.

Many rivers, mainly in Portugal, Spain and Italy but also in France, have multipurpose dams lacking or with inadequate fish passes. No countries report serious chemical obstructions, pollution having evident effects mostly at the level of reduced food availability for the eel (because of the reduction of invertebrate communities) rather than showing impacts on the stocks such as impedance of migrations, mortalities or chronic effects.

Riverine habitats amount to about *ca.* 2,700 km^2. In most rivers eel density falls consistently with distance from the sea, even when passes are present. Riverine eel fisheries are usually small local operations (as can be found in Ireland or Great Britain), sometimes sustained by means of within-catchment stockings of glass eel. On the whole, even if marked differences in trophic levels, and hence in environment carrying capacities, can be found, an average production of 10 kg ha^{-1} can be roughly estimated. This means that enhancement of local riverine fisheries could bring a four-fold increase in eel production in these habitats.

Eel stock abundance in lakes and reservoirs varies greatly across Europe, as a function of two main factors. Lake trophic level is of great influence on potential yields, in Sweden varying from 0.1–0.2 kg ha^{-1} in oligotrophic lakes to 3.4 in eutrophic lakes. Furthermore, in most lakes, yields are sustained by means of restocking, allowing a considerable increase in production. If a theoretical average potential yield of 10 kg ha^{-1} is assumed for lakes, the present level of exploitation amounts to only 11.5% of the potential yield.

The above suggests that eel stocks can be considered to be relatively underexploited, and habitats underutilised. The scattered cases of increase in yields point to the fact that restocking is the tool to achieve an enhancement in exploitation.

A series of considerations must be taken into account when planning the enhancement of local stocks and local fisheries. Some of these can be defined at a local scale. Local ecological conditions, such as carrying capacities, can differ greatly from environment to environment, even when the same type of habitat (lake or river or lagoon) is considered. Thus, all restocking policies must be locally programmed, and based on local research and/or feasibility studies. Furthermore, conflicts with other fisheries could arise, as in many habitats or catchment systems the prevailing interest might be directed towards other fish species.

Considerations on a global scale must also be taken into account, for instance the economic balance between costs and benefits. It has not been possible, on the basis of the Country Report information, to calculate or estimate the possible economic return of stocking operations. On the whole, the main factor limiting the achievement of a European-wide stock enhancement policy seems to be the reduced availability of seed, linked to the decline in recruitment.

3.2 Declines in recruitment

Country reports have confirmed the conclusions of the first report that there have been marked declines in eel catches throughout Europe over the last 20 years, beginning first at the northerly extremes of their range, with the collapse of some fisheries (Table 2.2). Whilst some declines have specific local causes (construction of major barriers, water quality problems, etc.), reductions in the initial recruitment of glass eel appears to be a stock-wide phenomenon. Possible common causes and implications for stocks and fisheries are reviewed below and a tentative estimate of the amount of glass eel needed to stock all currently suitable habitats in Europe is compiled.

3.2.1 Possible causes

Factors could be acting directly on glass eel recruitment or via effects on growth or reproductive stages. The following suggestions were made by the EIFAC (FAO) Working Party on Eel (1993):

Effects on freshwater life stages

(a) inability to use available habitats due to physical or pollution barriers in estuaries and rivers,
(b) loss of utilisable aquatic habitat, e.g. due to land-drainage or canalisation,
(c) acute and chronic effects of pollutants (especially persistent xenobiotic organochlorine compounds and heavy metals),

(d) the effects of infection by the nematode parasite *Anguillicola crassus* introduced to Europe in the 1980s from the Far East,
(e) factors affecting silver eel emigration and, possibly, subsequent reproduction and survival of early larvae,
(f) overfishing of glass eel, elver and, possibly, yellow and silver eel.

Effects on oceanic life-stages

Changes in ocean currents could have affected transatlantic migration of leptocephali (possibly associated with global warming and climate change).

3.2.1.1 Effects on freshwater life stages

The country reviews show that physical barriers can inhibit migration and hence recruitment into certain catchments. The impact on Europe-wide recruitment is, however, relatively low, with only about 28% of potentially suitable waters rendered inaccessible by natural and 3% by man-made barriers (Table 3.1). Furthermore, many barriers have been present in rivers for a long time, predating recruitment decline by more than 20 years. Many land drainage and tidal- and flood-control operations and other possible causes of loss of aquatic habitat similarly predate declines. Increasing environmental awareness means that more recent schemes have had to take account of the need to provide passage for (or compensatory stocking of) eel and other fish species. However, there are many local catchments and waters where structures and water management schemes still have major impacts on eel and other fish.

Pollution can be a barrier to migration, for example in major industrialised estuaries. Major improvements have been achieved in the treatment and control of sewage and other effluent discharges since the 1970–1980s. However, recoveries of populations have not been as rapid as might be expected if pollution had formed major barriers in the past (Knights, 1997).

Eutrophication and dystrophic crises have caused eel kills or decreases in production, but only on local scales (as in Italian lagoons). There have been no proven significant mortalities due to persistent pollutants such as heavy metals and organochemicals, except in major but isolated accidents, such as the Sandoz spill into the Rhine in 1986. Xenobiotic organochlorines are bio-accumulated but, according to Knights (1997), (a) there is no proof of major effects on survival, (b) declines in recruitment in both Europe and North America are not clearly correlated with periods of maximum contamination by organochlorine compounds and (c) the escapement of breeding eel from uncontaminated waters was estimated to greatly exceed that of eel that could have accumulated toxic levels.

Parasitism by *Anguillicola crassus* is now widespread in Europe, infestation rates are commonly high and damage to the swimbladder has been observed. However, studies reported over the last decade at meetings of the EIFAC Working Party on Eel have not shown any clear evidence for significant effects on yellow eel or on the transatlantic breeding migration of silver eel.

Emigrating silver eel can be injured or killed on passage through hydropower turbines and land-drainage pumps. However, the extent of water affected by such hazards is very small on a Europe-wide scale. The data summarised in Table 3.3 give a minimum escapement of potential spawners from known fisheries of 595 t. As this figure is based on the very small number of silver eel fisheries whose output is reported, the actual escapement of silver eel from fisheries would be expected to be well in excess of this level.

Artificially matured female eel can produce 2–3 million eggs (Boetius and Boetius, 1980) and the natural fecundity of American eel varies between 1.84 million to 20 million eggs for females between 45 and 113 cm (Barbin and McCleave, unpublished data). If the mean is 3 million for a 300 g female and minimum escapement of females is 300 t (i.e. 50% of 595 t), this represents 1 million females producing 3 billion eggs in total.

No information whatever is available on natural mortality of the silver eel in the course of its ocean migration and therefore it is not possible to quantify spawning stock on the basis of spawner escapement. Current fishery practice allows a very substantial escapement of silver eel to which must be added the production of spawners from the very large areas of unexploited eel habitat.

Concern has been expressed that overfishing of glass eel and elver, has had major impacts on stocks and even that the survival of the species might be endangered. There is reason to believe that natural mortality of these stages is very high and therefore a possibility that exploitation has little or no material effect on eventual spawner escapement.

3.2.1.2 Effects on oceanic life stages

Falling recruitment cannot be fully explained by factors acting during the continental stages of the life cycle. There have been parallel declines in recruitment of *A. rostrata* in Canada and these have occurred in the absence of any significant exploitation of glass eel or later life stages (Castonguay et al., 1994). Common oceanic factors acting on both species are implicated.

Almost nothing is known about the oceanic migration or reproduction of silver eel. However, declines in glass eel catches in Europe are generally correlated with one another, with those for Canada and also with the position of the north wall of the Gulf Stream (Knights et al., 1996). This oceanographic feature lies off the North American shelf, south of Newfoundland. It represents the major boundary between subpolar and subtropical currents which may be associated with spatial distributions of weather and sea-surface temperature fronts.

Little is known about the transoceanic migration of leptocephali and current systems in the western Sargasso and north-eastern Atlantic are poorly understood. Castonguay et al. (1994) discussed indirect evidence for slowing of the Gulf Stream in the 1980s. White and Knights (1994) and Knights et al. (1996) suggested that a northwards shift in the north wall of the Gulf Stream could have caused some leptocephali to follow longer, more northerly routes. This could have exposed them to less favourable conditions of temperature or of food availability) for growth and survival. Indirect evidence for this proposition comes from analyses of Den Oever glass eel sampled between 1960 and 1996 by Dekker (1996a). He found that declines in numbers caught between 1960 and 1996 correlated significantly with decreases in body length. He interpreted the decreases in body length as being due to poor feeding of leptocephali during the oceanic migration.

Despite the above relationships, there is no conclusive evidence of specific cause–effect relationships between changes in North Atlantic currents and recruitment declines.

3.2.2 Implications of declining recruitment

There appears to be no single proven cause for declining recruitment. Combinations of factors will have negative impacts but oceanic rather than continental factors are likely to be the most important overall.

Taken together with data on unexploited stocks and escapement, it appears that at the moment, the species as a whole is unlikely to be directly endangered, but the situation needs to be carefully monitored. There are many local stocks that could be enhanced by improved management. The greatest benefits could be gained from stocking lakes (especially in more northerly countries), closed saline waters (especially Mediterranean lagoons) and suitable areas of the Baltic. Country reports show that these are the waters that have historically supported major fisheries but where yields have declined most markedly because of recruitment declines. The relatively high costs of seed stock require that the distribution of stocking efforts must be carefully controlled to maximise effectiveness. This requires better knowledge of optimal stocking densities, population dynamics, potential yields, etc. and further research and management interventions are required.

Table 3.2 Current stocking and requirements for optimal management (summary of data from Annex 2)

Habitat	Surface area km^2	Natural recruitment t	Artificial stocking t	Stocking rate kg ha^{-1}	Additional requirement t
Fresh still	29,971	7	25	0.10	268
Fresh running	2,717	60	5	0.10	-38
Saline closed	17,466		3	0.14	232
Saline open	21,046			0.01	21
Baltic	16,135			0.10	161
Total	87,335	67	33	0.10	644

3.2.3 Requirement to optimise fishery and escapement

On the basis of the existing knowledge, the requirements for stocking material to optimise the density and production of continental waters can be estimated (Table 3.2). The basis for this estimation are explained in Annex 2). Within the EU, a total of 87,335 km^2 of suitable habitat is available. Stocking rates vary over latitudes and habitat types, but the average justifiable minimal level is 0.1 kg ha^{-1} equivalent to a potential stocking volume of 744 t of glass eel. Natural recruitment has been quantified in only a few cases, amounting to 67 t. Taking into account 33 t of glass eel being stocked annually in recent years, it will require at least 644 t of glass eel to bring all suitable habitats to optimum production.

The actual catch of glass eel (920 t, *Report 1*) is more than the amount needed (744 t, Table 3.2) to stock all European continental waters with the minimal density required for each ecotope. This implies that the current level of spawner escapement is not limiting the production of an adequate number of recruits for the species as a whole, but still might be inadequate given the current geographical distribution of recruits.

3.3 Population dynamics and relevance to management

In order to manage eel stocks, it is essential to be able to accurately assess and monitor long-term recruitment, stock distribution and size, the effects of natural and fishing mortality and the escapement of silver eel. Population densities, production and yields need to be quantified in relation to habitat quality in different waters throughout Europe, especially in relation to assessing the efficacy of management interventions, such as stocking. Density and growth rates are important factors because they tend to show a negative correlation with the production of larger female eel of high fecundity and hence value to the breeding stock.

Accurate assessments of population dynamics are made difficult by the multi-stage life cycle of eel, wide variations between different habitats and the problems inherent in accurate and reliable sampling (Knights et al., 1996). The data available in the literature tend to be fragmentary, originating from relatively few investigations in each country and from unbalanced sampling over the geographical range of *A. anguilla*. Data derived from the literature (Table 3.3 and Annex 3) thus demonstrate wide variations.

Table 3.3 Yields of silver eel fisheries and estimated quantity of escapees (summary of data from Annex 2)

Habitat	Surface area km^2	Known yield t	Escape rate %	Escapement t
Fresh still	29,971	301	12	71
Fresh running	2,717	250	10	28
Saline closed	17,466	300	12	33
Saline open	21,046		10	
Baltic	16,135	1,078	30	462
Total	87,335	1,929		595

Key aspects of population dynamics during different life stages are as follows.

3.3.1 Assessment of glass eel, elver and bootlace eel recruitment

Glass eel can be sampled experimentally by boat- or hand-netting but resources have rarely been made available for long-term monitoring. The sampling programme at Den Oever in the Netherlands is an ideal example and has provided good evidence of long-term changes (e.g. Moriarty, 1990a, 1996a,b; Dekker, 1996a; Knights et al., 1996). Fishery catches can, theoretically, be used but catch–return data are generally very unreliable and dealers are unwilling to divulge commercially sensitive information. Best-estimates of commercial catches have, however, been of benefit in assessing recruitment. Export data can also be of use but these are difficult to interpret because of the lack of detail now required for intra-EU trade, plus complicated patterns of re-export and movement of shipments around Europe (Knights et al., 1996). The situation is now further complicated by increasing amounts of exports to the Far East.

Accurate sampling of small juveniles is difficult because they are not easy to capture in nets or traps or by electrofishing. Some of the best indications of upriver migration and recruitment come from pass-traps mounted on barriers in estuaries and rivers. Good data sets have come from commercial trap-and-transport systems (e.g. in the Bann–Lough Neagh fishery in Ireland) and from experimental systems (e.g. Knights et al, 1996). Long-term studies have illustrated declines in recruitment, agreeing with the conclusions drawn earlier in this report from. Detailed catchment studies show that barriers interfere with upriver migration and recruitment (White and Knights, 1997a).

3.3.2 Assessment of eel stock density

Eel can be sampled by electrofishing in fairly shallow and transparent waters. Capture efficiency is often low, however, especially for small eel. It is also difficult to reliably mark eel. Recapture rates of marked eel are commonly < 2%, therefore standard catch-depletion methods of population estimation are rendered inaccurate. However, indications of relative density can be gained. Densities can also be estimated for catchments where elver entry and silver eel exit has been quantified, e.g. as in the Imsa system in Norway (Vøllestad and Jonsson, 1988). Data in Table 3.3 show a very wide range of densities in European rivers, partly explained by sampling efficiency but also by differences in habitat and whether local populations are dominated by small or large eel. Ranges are between 0.1–1300 eel 100 m^{-2} and 0.5–328 kg ha^{-1}. Interpretation of such data for management purposes is not easy, but relative differences can be related to habitat quality (e.g. average temperature and productivity) and to distance inland and to the impacts of migration barriers (e.g. see Naismith and Knights, 1993).

In deeper open still-water and saline habitats, electrofishing cannot be used. The area sampled by fyke nets in such habitats is unknown and thus no density data are shown in the tables. Shallow open waters, such as Lake IJsselmeer, can be sampled by trawling.

3.3.3 Assessment of production and yield

Biological production can be related to habitat quality, carrying capacities, etc. but problems of assessing biomass, recruitment and growth rates mean that few such data are available. Sampling methods are biased towards the capture of large eel, fyke nets only being satisfactory at catching eel > 30–40 cm. Marking and recapture also pose problems, as discussed above. Detailed data shown in Annex 3 indicate that more southerly waters (e.g. Italian lagoons) tend to be the most productive habitats and that production in lakes exceeds that in rivers.

More information is available on commercial yields of yellow and silver eel, but mainly from closed lakes that have been stocked at known levels. Yields tend to be lower in more open waters because of the difficulties of efficient capture by fyke net or long-lining and by silver eel nets and traps. For the purposes of European comparisons, average annual yields (in kg ha^{-1}) were assumed to be 10 for fresh still waters, 10 for fresh running waters, 20 for closed saline waters and 5 for open saline waters. Some local differences were taken into account, e.g. lower values in the Baltic (because of low stock densities and difficulties of capture) but a potentially very high value (40 kg ha^{-1}) in productive closed Italian lagoons. Growth rates tend to be decrease with increasing latitude because of lower average water temperatures and shorter growth seasons which in turn affects age and length at metamorphosis to the silver eel (Vøllestad, 1992). High density stocks tend to produce a preponderance of males (Knights and White, 1997a).

In relation to escapement of silver eel, the consensus was that this was generally in the order of 12%. In the Baltic and Lough Neagh (Northern Ireland) where there is more knowledge because silver eel are exploited, values were thought to be nearer to 30%.

3.3.4 Natural and fishing mortality

Ideally, information is needed on the relative impacts of fisheries compared to natural causes of mortality at different stages of the life-cycle. This would help clarify whether stocks are being over-exploited and whether controls on fisheries are required. However, there are few data available for natural mortality between immigrant glass eel and emigrant silver eel stages. This is because of difficulties in sampling populations and accurately determining ages, plus the lack of information on fishing effort. Stocking studies suggest that natural mortality is in the order of 75% over the total continental life span. The impacts of fishing mortality are rarely known. In Lake IJsselmeer, annual fishing mortality (F) is in the order of 0.5 (Dekker, 1996b). The fishing mortality in Lough Neagh (N. Ireland) is assumed to be of a comparable magnitude.

3.3.5 Conclusions

In order to better apply the precautionary principle to local, regional and international management, more information is required on key aspects of the biology of eel and the impacts of fisheries and other factors. Information currently available is fragmentary and based on relatively few experimental studies, except for a few fisheries, such as Lough Neagh and Lake IJsselmeer. Localised studies may be appropriate but the major research requirements that need to be co-ordinated and inter-calibrated throughout all countries are:

More accurate, extensive and intensive monitoring of

(a) glass eel catches and recruitment
(b) upstream elver/yellow eel migration and recruitment
(c) stock distribution, density, age, growth rates and sex ratios
(d) escapement of silver eel

Further analytical and methodological research, involving studies of

(a) natural biological production and commercial yields
(b) natural vs. fishery mortality

The above studies need integrating with others on the possible impacts of anthropogenic factors, such as migration barriers, habitat quality and disease. Whilst of low priority in the short-term, further knowledge of the migration of silver eel, reproduction and Leptocephalus biology could clarify oceanic causes of declining recruitment and, in the long-term, the possibilities of artificial propagation.

3.4 Management objectives

3.4.1 Overview

Management of eel stocks has been practised for centuries all over Europe, without centralised management objectives. In most cases, local objectives are unclear or only implicitly indicated. A thorough review of these objectives goes beyond the scope of this report. However, the following main streams can be identified.

3.4.1.1 Food supply

Although the eel once contributed directly to the diet of fishermen and local communities, it has assumed the status of a luxury food item and the high price of all life stages and the adequate trading infrastructure in even the smallest outpost of the eel's distribution area, have made this objective a thing of the past.

3.4.1.2 Rural employment

The first phase of the Concerted Action estimated that 25,000 people acquire an income from the eel fisheries. Almost all of the existing management actions discussed in Section 2.5 refer – explicitly or implicitly – to the maximisation of their income by maximisation of their yield.

3.4.1.3 Maximisation of production of natural resources

Although this objective has often been stated in close connection with the previous one, explicit references to this ideal have become quite rare. The crucial distinction with the previous objective lies in the value attached to the optimal exploitation of natural resources, independent of their economic potential.

3.4.1.4 Protection of the population and species

The recent decline in recruitment has elicited serious concerns about the possible endangerment of the eel species. It has been argued that the observed recruitment decline might mainly be due to oceanic effects but that the situation is exacerbated by human activities such as reduction of habitat in continental waters, overfishing and pollution (see Section 3.2.1).

3.4.1.5 Conservation of biodiversity

The eel has a significant position in the aquatic ecosystem as an important predator and as a contributor to the diet of other highly esteemed aquatic predators such as otters and herons.

3.4.1.6 Suboptimal management

In many cases, current practices do not conform to any of the objectives listed above, because of a mismatch between stated objectives and the actual state of affairs. Overfishing of yellow eel stocks, insufficient control of the glass eel disposition or lack of knowledge on the current state of fisheries occur in several countries (Chapter 2). However, in all countries actions are taken by the managers (Section 2.5) in response to one or more of the objectives listed above.

3.4.2 Conflicting objectives

Management actions to enhance the European stocks are proposed in the subsequent chapters. These seem to be in conflict with some of the objectives listed here. Objectives 3.4.1.4 and 3.4.1.5 require that eel eventually end up free, while objective 3.4.1.2 requires as much eel to be caught in the end as possible. Given the geographical stratification of the life stages of the eel and the corresponding geographical stratification in its exploitation, this apparent conflict between objectives conforms to contrasts between countries in the relative weight they assign to the objectives, namely in contrasts between southern and northern Europe.

However, assigning global and mandatory priorities to the objectives at the international level would introduce an unprecedented and unnecessary discontinuity in the management of the eel population. Local management actions to enhance the fisheries by additional stockings or controls to the fisheries have so far only acted to enhance the local stocks. Thereby, management actions have unintentionally contributed to the role of the eel in the ecosystem and may be manipulated to improve the contribution to the escapement of maturing eel to the spawning process. Historically, there has always been a more or less stable balance between the different management objectives, a balance between 'to have' and 'to eat'.

3.4.3 Spawning stock biomass

There is a point to be made with respect to the safeguarding of the spawner escapement and the possible control of the eel fisheries. As indicated in Section 3.2, the Minimum Biological Acceptable Level for the spawning stock of eel is unknown, but it is unlikely that the current escapement (minimal estimate: 595 t, Table 2.3) would be insufficient to sustain the population. Additionally, recent recruitment levels are adequate to stock all of the suitable habitats in the EU (Section 3.2.3), provided that they are redistributed over the continent.

So far, few silver eel fisheries are known to have 100% efficiency; in many countries, there are legal measures to prevent full efficiency. In the few cases in which an actual estimate of the efficiency could be made, results indicated an efficiency of less than 75% (Section 2.4). A notable exception is the extensive Italian aquaculture systems, where the lagoons have been managed in order to retain all silver eel.

Therefore, unless unprecedented improvements in the efficiency of silver eel fisheries take place, there is no unambiguous ground for formulating additional control measures for the conservation of the species, nor for setting priorities for the objectives listed above.

3.4.4 Conclusion

The objectives of management of eel fisheries vary between countries and are often only implicitly known. At the international level, no management objective has as yet been stated explicitly. Potential management measures to enhance the continental stock will contribute to all management objectives. Potential alterations in the priorities of objectives might be considered at national and international levels, but they need not be based on the precautionary approach to fish stock management, unless future developments and results of research indicate to the contrary.

3.5 Management options

The major tools available to fisheries managers are to control eel fisheries or to compensate for lack of recruitment and low stocks by (a) stocking (using purchased eel or inter- and intra-catchment trap-and-transport) and (b) provision of passes on barriers to enhance recruitment into freshwater catchments. Artificial propagation could in theory be used to spare wild-caught seed stock. However, it is extremely unlikely that this will ever be feasible, given the marine reproductive strategies of eel and the oceanic nature of the planktonic Leptocephalus stage.

The first stage in any management plan is to decide on objectives and priorities, which requires data on current stocks, population dynamics, etc., as discussed in Section 3.3. Catch return data are then required to provide information for fisheries managers.

3.5.1 Controls on fisheries

Such measures include restrictions on fishing areas, times or methods to prevent or reduce exploitation. There is a lack of consistency in the specific controls on gear, closed seasons, etc. used in different European countries. These have evolved to match local fishery conditions and traditions and some measures are not specifically directed at protecting eel but to the management of other species or other constraints (e.g. conservation or navigation). These national differences make it difficult to propose common legislation applicable to all European fisheries.

3.5.2 Stocking strategies

Stocking can be a cost-effective means of restoring or maintaining yields in fisheries and meeting biological conservation requirements (Knights and White, 1997a). It is essential in catchments with barriers where passes are ineffective and in isolated waters suitable for eel. Any increases in escapement of silver eel production (especially of large females of high fecundity) will also enhance the panmictic stock.

There have been relatively few detailed and long-term studies of stocking to inform fisheries managers. These have been reviewed by Knights and White (1997a). Ideally glass eel, elver and yellow eel should be caught for transfer within catchments but these are currently rarely enough available (except for the Atlantic-facing estuaries of the UK and France). Imports have to be relied upon but then high costs are a major disincentive, as are restrictions imposed by countries such as Sweden to prevent disease transmission. Quarantining and on-growing can help overcome some of these problems but increase costs further.

Careful pre-stocking assessments are required, including clarification of who is to pay for stocking and who owns catches, given the context of local and national regulations and jurisdictions over fishing. Stocks must be carefully exploited to maximise commercial yields. Low temperatures, short summers and poor habitat quality will restrict growth rates, increase the length of time between stocking and exploitation and decrease the length of the fishing season. To maximise the capture of larger and more valuable eel, it is important to minimise escapement and, if possible, be able to trap immigrant silver eel. Stocking density and exploitation rates must also be adjusted to ensure that optimum sex ratios are maintained. Lower densities generally promote the development of longer maturing and larger females of high fecundity.

Knights and White (1997a) concluded that more detailed and long-term research is needed on optimum stocking rates in different waters. In warmer and more productive still waters, these generally appear to be about 0.1 kg ha^{-1} (i.e. about 300 glass eel/elver ha^{-1} or an equivalent weight of juveniles). The potential yield is about 20 kg ha^{-1} at 40–50 g per recruit. Data on survival rates are sparse but the evidence reviewed in Table 3.3 (and Annex 3) suggests a typical figure to be 20–30% between glass eel/elver stocking and final exploitation. To maintain the same yields in colder and less productive lakes, stocking rates should be reduced to 150–200 eel ha^{-1}. In both cases, numbers ha^{-1} can be reduced if on-grown or wild-caught yellow eel are stocked but this will increase initial stocking costs.

Data are also sparse for rivers but Knights and White (1997a) recommended that eel should be scatter-stocked (to minimise density-dependent mortality) in rivers in the summer, when temperatures are high enough to encourage dispersal. Typical stocking densities used are 1–2 eel m^{-2} in low productivity waters, rising to 4–5 eel m^{-2} in warmer waters with plenty of bottom cover and/or marginal vegetation and high productivity of macro-invertebrate prey.

3.5.3 The use of passes to enhance recruitment into freshwater catchments

Passes on migration barriers can play a useful role in enhancing migration and recruitment of young eel into certain freshwater catchments. However, quantitative data on their cost-effectiveness is lacking (Knights, 1997).

The first priorities are to determine the needs for passes and to derive sustainable and cost-effective management objectives. Important site-specific factors are: (a) the number, types, purposes, management and distributions of obstructions in a catchment, (b) estimation of the significance of each in terms of passability and the availability of alternative routes, (c) the extent and quality of habitat that would be opened up to migrants, (d) the location and effectiveness of any existing fishways and (e) the number and sizes of eel that might benefit. To quantify the impacts of barriers, past and present commercial and fishery survey data should be analysed. Impacts can also be assessed by sampling immigrants directly using simple pass-traps or predictions made from information from similar catchments. Insufficient information is available in the literature to set precise recruitment targets but Knights (1997) concluded that typical targets for young migrants are about 40–50 per 100 eel m^{-2} for productive river systems and 10–20 per 100 eel m^{-2} for less productive ones. Another approach is to set annual recruitment targets on the numbers of migrants caught in experimental pass-traps.

A wide variety of pass designs is available but basic requirements are: (i) a flow of water to attract fish towards a pass, (ii) suitable design and placement of the entrance and exit, and (iii) suitable water velocities down a pass and/or the provision of some form of climbing material to aid ascent. Barriers can be rendered climbable by providing a rough surface (i.e. to form a *rock wall*). Eel ladders can be provided up which eel can climb. These can consist of by-pass channels or pipes or troughs attached to barriers, provided with suitable climbing material, e.g. geotextiles, brushes or horticultural netting.

Long-term post-construction monitoring is essential to ensure that passes are efficiently maintained and managed and to provide information for other schemes. Fitting traps on passes will provide useful information on eel migration, recruitment, population distributions and dynamics. Traps can also be used to provide eel for stocking.

3.5.4 Discussion

Doubts have been expressed in this report that the European eel is an endangered species. However, recruitment has been shown to have declined drastically throughout Europe, particularly in more northerly and southerly countries. This has severely impacted some natural stocks and commercial fisheries and it is possible that the recruitment situation could worsen in the future. The precautionary principle should therefore be applied in order to protect the species, as well as to help maintain sustainable stocks for commercial exploitation and for conservation in a general biodiversity context. Overall, however, there is little consistency throughout Europe in management objectives, practices and enforcement.

Catch return data are commonly required to provide information for managers. However, catch-return data are generally of poor quality (Knights et al., 1996) and all country reports noted that underclaiming of catches by fishermen was widespread. Ideally, commercial catch data should be collected in a standardised way in all countries to help quantify recruitment and exploitation.

It could be argued that the current high levels of commercial fishing of eel (especially of glass eel) should be curtailed by law. This would be difficult to achieve, requiring changes in fishing regulations in the main producing countries and, possibly, payment of financial compensation to fishermen and dealers. Restrictions would also be difficult to enforce. It is also debatable whether fishing has a significant impact on the total panmictic European stock, given probable low fishing mortalities, high escapement and the amount of aquatic habitat that is not exploited at all.

If oceanic factors are of paramount importance in controlling initial recruitment, it could be argued that there are no practicable and cost-effective means by which the overall panmictic European eel stock can be managed. Given that glass eel/elver fisheries are geographically localised, fishery controls would only directly offer significant benefits to the associated river catchment and local stocks.

Ideally, under-utilised habitats and unexploited low density stocks could be augmented to encourage production of mature males and females to enhance the breeding stock. This would have to be carried out on a large scale to make any significant extra contribution to natural production in unexploited fresh, brackish and coastal waters. Furthermore, any recoveries in recruitment might be negated by the demands for glass eel/elver for aquaculture and direct consumption in Spain.

However, to enhance the utilisation of catchments and hence fisheries and natural community structures, the provision of passes on barriers is a valuable management option, as is stocking, using trap-and-transport systems within and between catchments and countries. Care must be taken, however, to match stocking densities to the carrying capacities of different habitats of different quality. Ancillary tools are to protect habitats currently used by eel, to enhance the quality of these habitats and any new ones opened up by stocking and to aid escapement of silver eel where appropriate.

4. MONITORING AND RESEARCH

The European eel is a highly migratory, catadromous but essentially marine fish species, which only completes some of its life stages in continental waters. Oceanic and continental distribution present a complete contrast: although the hypothesis that there is only a single spawning stock in the ocean has not been seriously challenged, this stock has never been observed. In continental waters the distribution of the eel is characterised by extreme scattering over almost all water bodies but information is only available on local stocks.

The implications of the common responsibility for the single spawning stock and the practical problems of monitoring and managing the scattered continental resource are discussed below. This chapter summarises past management-related research on eel and proposes a baseline for future co-operative monitoring and research, integrating the national and international levels.

During the discussions of the EIFAC/ICES Working Party on Eel and the Concerted Action in 1996, it was emphasised that the Management Plan to be compiled by the Concerted Action would have a weak basis, unless supplemented by an international scheme for monitoring and fundamental research to resolve essential biological questions. Therefore, the implications of the achievements of the Concerted Action for future monitoring and research were considered.

4.1 Objectives

Eel fisheries have so far been managed only on a local or national basis, with management objectives varying from local employment through maximisation of food production to conservation of the population at regional scales (Section 3.4). In the absence of any perceived need for international management, the eel fisheries have been run for many decades as if they represent parallel fisheries on independent local stocks. Although this management system appears to conform to the subsidiarity principle, it has not been based on a deliberate application of the principle. Recently the question has been posed as to whether management at the national level can sustain the stocks throughout the distribution area.

Since the 1980s, several independent trends have raised international issues in eel management and research:

4.1.1 Recruitment from the ocean has declined all over Europe (Section 3.2).

4.1.2 The yield of fisheries on the growing phases of the eel has shown a gradual decline over the past decades (Section 2.3).

4.1.3 National governments have cut down their funding for monitoring and research related to eel fisheries. The mismatch between the recent pressure for international management advice and the reductions in regular research budgets has stimulated eel workers to apply co-operatively for international funding, as exemplified by this Concerted Action programme.

4.1.4 Most recently, the demand for European glass eel from eastern Asia has suddenly increased very sharply. Aquaculturists and inland fisheries organisations are alarmed at the international level, because of their inability to afford adequate amounts of stocking material.

Management of inland eel fisheries has long been considered to be a national responsibility only. However, because of the location of the common breeding stock in the open ocean and the highly migratory status of the stock, international management of the continent-wide aspects of the stock is a prerequisite for sustainable management at national scales.

The following points are of importance :

4.1.5 As the EIFAC/ICES Working Party on Eel reported in its 1996 meeting in IJmuiden, concern about the minimum spawning stock required to safeguard recruitment and the sustainability of the fisheries leads to consideration of the concept of the Minimum Biological Acceptable Level (MBAL) for this stock. In the case of the eel, this would require setting a minimal level to the number of escaping eel, which can contribute to the oceanic spawning process. Since all known spawning takes place outside territorial waters, the safeguarding of MBAL is necessarily an international objective (Section 3.4).

4.1.6 The eel industries support employment in rural areas and fishing communities. Although incomes from fisheries in individual waters are generally small, the total impact all over Europe is substantial. Local management by national or regional authorities focuses only on short-term local issues at the expense of enhancing socio-economic benefits throughout Europe.

4.1.7 Eel represent a significant component of the aquatic ecosystem, including their considerable contribution to the diet of many other fish and semi-aquatic predators such as otters, cormorants, herons, etc. This implies that the management of the eel stock should take account of the broader needs of biodiversity conservation. Recent bird protection schemes require so-called fly-way management, consistent management throughout the fly-way of the predators. A similar approach should be considered for such a highly migratory species as the eel.

4.1.8 Eel and eel fisheries are found all over Europe, but most intensively in areas of maximal human environmental impact, namely the coastal fringe of the continent. Consequently, eel have been chosen as an indicator species of continent-wide monitoring programmes on pollution. The decrease of the eel is certainly an integrative signal of environmental stress caused by man, including the effects of pollution, habitat loss and degradation and migration barriers.

4.1.9 The *precautionary approach* has been adopted in several international conventions. Since the eel has been managed on varying local scales, management objectives have varied and are often unclear. Since the precautionary principle is given higher priority than local, short-term objectives, a thorough re-examination of the management structure of the eel stock in Europe is urgently needed.

4.2 Monitoring

The eel represents essentially an international, marine resource, which only completes part of its life cycle in continental waters, where it is exploited. Because individual eel fisheries represent only the pixels of the complete picture of the eel in Europe, it has taken considerable time to realise that the total eel stock is under severe stress. Consequently, when the common responsibility for this unique living resource is considered, a first requirement is that the monitoring programmes are tailored to the international management objectives, so that management actions can be related to the true state of the stock. Over the years, the impact of the exploitation has changed considerably, because of increases in the level of exploitation and because of natural changes in the stock. Consequently, sustainable exploitation can only be achieved through continued monitoring of the stock and its fisheries.

4.2.1 Existing national monitoring

The immigration of glass eel coming from the ocean is presently monitored at 13 sites along the European coast, either by surveying the fisheries or by dedicated sampling. Personnel involved: ± 8 man-years.

Specific monitoring studies of the growing phases of eel are scarce, lake IJsselmeer (Netherlands), Shannon catchment (Ireland) and the Baltic coast of Sweden probably being the only substantial ones. Personnel involved amounts to 5 man-years (1 in Netherlands, <0.1 in Ireland, 4 in Sweden).

Additionally, more general fish surveys in France, Sweden, Great Britain and to a minor extent the Netherlands, related to general fisheries and pollution management do provide incidental data on eel. However, sampling and data collation and analysis methods vary widely and need integrated approaches. Total personnel for the general surveys are estimated at ± 50 man-years. The share of the eel in this cost is difficult to estimate; a first bold guess amounts to 10%, i.e. 5 man-years.

There is at present only one comprehensive study of the interplay of stock density and fishing effort: the assessments of the lake IJsselmeer (Netherlands) eel fisheries, which are annually reported to the national government. Personnel : 1 man-year.

Many countries collect catch statistics, but these are rarely complete: incomplete coverage, as well as under-reporting, makes the use of these statistics questionable even at the national level. The reliability of these data tends to deteriorate, although eel scientists have succeeded in unearthing more of these sources in the past few years. The sharply increasing price on the international glass eel market has had a pronounced effect on the fishing effort in the glass eel fisheries. The statistics on the total yield of glass eel have often been used as rough indicators of recruitment, but they are now more indicative of the impact made by man than of the well-being of the eel stock itself.

4.2.2 Existing international monitoring

At the meetings of the EIFAC/ICES Working Party On Eel, the data available from national surveys on glass eel recruiting from the ocean have been summarised. Although similar declines are apparent, the Working Party has so far not attempted to derive one single index of recruitment. Possible contrasts amongst data series for different glass eel fisheries could provide information on still obscure processes acting during the oceanic life stages.

Individual members have presented overviews of the eel fisheries in their countries on several occasions, but in the absence of common management objectives or common factors driving the fisheries, no international research co-ordination has taken place in the past.

All the current inputs to an international overview have been run at national expense. This has severely limited the personnel invested and resulted in fragmented and uncoordinated studies. It is unlikely that further investments from national sources will be substantial and hence international initiatives are even more imperative.

4.2.3 Future requirements for monitoring

Requirements for future monitoring are closely linked to the management objectives to be set at the international level. Whatever the objectives, these will probably not require a complete coverage of all individual rivers and lakes on a yearly basis. Monitoring has so far relied on a small number of the better-documented cases. This information has been used as if it represented a complete survey. It is doubtful whether one can improve upon the completeness on a permanent basis, or even whether it is worthwhile pursuing. Establishment of a set of selected cases for yearly monitoring, however, is a feasible objective and sufficient information is now available for selecting a reliable sample of the full survey of all waters, which is unachievable on a yearly basis.

The selection of this sample of sites must reflect the following (Section 3.3):

4.2.3.1 *The strength of the recruitment to the continent,* independent of the socio-economic factors driving the fisheries and independent of local (e.g. climatic) factors. The experiences at the currently running series at Den Oever (Netherlands, constant effort in research sampling) and in French estuaries (partly discontinued surveys of commercial fishery based on effort and catch) provide a basis for future selection of sites and methods, as can experiences in by-catches of eel in marine planktonic surveys (ICES International Young Fish Survey).

4.2.3.2 *The density and production of the continental stocks contributing to the spawner escapement to the ocean.* In principle, direct monitoring of the escapement should definitely be preferred, but this has seldom been achieved so far. A notable exception are studies in the Baltic (involving long-range tagging studies), a prime production area of female spawners. Monitoring of yellow eel stocks, a pre-spawner survey, is a second option for monitoring the spawner escapement elsewhere, in view of the known problems of monitoring silver eel migration. Studies in lake IJsselmeer (Netherlands), the Severn and the Thames and Avon (Great Britain) basins provide the required basic experience.

4.2.3.3 *Monitoring of exploitation should reflect the different fisheries on various life stages of the eel.* In view of the geographical differences of the fishing techniques throughout Europe (glass eel fisheries around the Bay of Biscay, yellow and silver eel fisheries in central and northern Europe), this conforms to a geographical stratification of the monitoring. This would also yield information on the contributions of eel fisheries to rural economies and fishing communities.

All such monitoring studies should be run at spatial intervals around the continent. However, before selecting the appropriate sampling sites, an intensified survey should be undertaken, aiming towards complete coverage of at least the most important catchment areas. This should be repeated at intervals of approx. 10 years, with annual sampling at sites chosen following the first survey.

In addition to the monitoring related to the stock-wide management objectives, local management might require additional activities. Since the local objectives vary widely over Europe, no common line emerges at the international level. However, it would be more cost-effective for national monitoring to fit in with the internationally co-ordinated monitoring or at least to inter-calibrate national monitoring studies in their own right.

4.3 Methodological research related to monitoring

4.3.1 Historic overview

Almost all countries have at some time invested in methodological research on eel, in parallel with the monitoring activities of their local eel stocks. Three main life stages, in running and still waters and with or without commercial exploitation using many different fishing techniques have resulted in a wide range of monitoring methods being used. New monitoring series have evidently been based on past experiences, but – because of the wide range of objectives and settings – no standardisation or intercalibration has been attempted.

In the 1980s, the EIFAC/ICES Working Party On Eel took the initiative for two reviews on methodological issues (ageing: Vøllestad et al., 1988, and tagging: Nielsen, 1988).

4.3.2 Required methodological research

The requirements for methodological research follow directly from the requirements for monitoring listed above:

4.3.2.1 *The provision of a standardised baseline survey of the eel fisheries throughout Europe.* This survey will provide detailed information, not accessible at the international level on a nation by nation basis, supplementing the outline material assembled by the Concerted Action.

4.3.2.2 *The selection of sites for continuous monitoring.* This requires considering the local conditions of specific cases, as well as the consequences for (and limitations imposed by) national management. Ideally, existing long time series of local monitoring activities should be incorporated.

4.3.2.3 *The inter-calibration of monitoring methods,* paying due attention to limitations set by the widely differing habitats and life stages of the eel to be sampled.

4.3.2.4 *Exploration of the potential for direct monitoring of spawner escapement* in a wider setting than just the Baltic.

4.3.2.5 *The inter-calibration of fisheries assessment methods,* distinguishing separate methods for fisheries on separate life stages (glass eel fisheries around Bay of Biscay, yellow and silver eel fisheries in central and northern Europe).

4.4 Analytical research

Management of fish stocks is generally based on analytical insight into the processes governing production and exploitation on the one hand and current information on the status of the stock (monitoring) on the other. Concerning the biology of the eel, the analytical basis for management is relatively weak. The discussion here will focus on the aspects relevant to the management at the international level.

4.4.1 National

The earliest reference to experimental research on fish ecology is undoubtedly Aristotle's description of the spontaneous appearance of eel in a pool which had previously been carefully cleaned of eel. Since those days, many aspects of the biology of the species have been studied. These research projects have been run almost entirely on a national basis; the greater part of the impressive work by Johannes Schmidt in the Atlantic Ocean was even privately funded. Current investment in research relevant to eel management and conservation is probably in the order of magnitude of 5 man-years per annum.

It is therefore not surprising that many aspects of the biology of the eel are not yet fully understood: age and growth, sexual differentiation, mortalities during recruitment and inland life and, most prominent of all, the reproductive process itself, are incompletely known.

4.4.2 International

During the 1991 meeting of the EIFAC/ICES Working Party On Eel in Dublin (Ireland), it was realised that international co-operation might yield insights that are not achievable at the national level. Consequently, three co-operative projects were set up (recruitment, growth, pollution) for compiling data available from national projects and analysing the general trends. These projects were run at national expense. Because of the limited budgets available, this approach has met with only limited success. Only the review of pollution has been finished (Knights, 1997).

At the 1993 meeting of the EIFAC/ICES Working Party On Eel in Olsztyn (Poland), the exploration of potentials for co-operative work was given a logical extension with the compilation of a list of research subjects, aimed at a better understanding of the biology and exploitation of the eel. This list also included projects to be run at the international level, on a co-operative scale rather than simply the integration of national projects. However, the Working Party felt unable to assign a priority ordering and the initiative was left to individual members. Again, the steady reductions in national budgets have inhibited this approach.

In spring 1996, four independent proposals for studies on eel were submitted under the FAIR-programme (age determination, recruitment simulation, genetics, tagging of spawners). The common line in the comments received on each of these proposals was that the Management Plan of the ongoing Concerted Action should be completed first. This implies a linkage between management requirements and the funding of analytical research.

In the autumn of 1996, at the meeting of the EIFAC/ICES Working Party On Eel in IJmuiden (Netherlands), it was agreed that the Management Plan to be compiled would have a weak basis unless it would be supplemented with an international scheme for monitoring and for an increased level of fundamental research.

4.4.3 Required analytical research

4.4.3.1 Analytical research: eel in contrast to other species

Local management of eel fisheries has been practised for centuries. Although several processes (growth, sexual differentiation, etc.) are not analytically understood, one can only conclude that the knowledge-base is sufficiently developed to sustain or enhance the rural fisheries on a local scale. Improvements can be expected from long-term analytical research funded on the usual competitive basis, provided that eel research in itself is competitive relative to research on other species. In this respect it is noted that process-oriented research rarely chooses the eel as its subject, because of the relatively poor understanding of its biology compared to other species. The extreme adaptability to environmental diversity makes the eel a slippery animal. Temporary special dispensations for research on eel might be needed to allow eel research to catch up with that on other species.

4.4.3.2 Analytical research related to proposed international management

On the continental scale, stocking material is transported, mostly from the southern Atlantic coasts of Europe towards central and northern Europe. The effects of these fishing and stocking practices are poorly known, neither at the source nor at the seed-receiving side. Additionally, the transport from one side of the population range to another might introduce effects on homing to the breeding grounds or the population genetics of the species.

Given the immense number of newly recruiting glass eel entering the rivers on these coasts, it is likely that the natural recruitment could exceed optimal carrying capacities for local catchments, such as the Loire and Severn, but the fishing pressure exerted on the incoming recruits is also immense. Since any potential effect on the escaping glass eel and subsequent recruitment will only become evident many years later, the depletion of the stocks in the regions of glass eel fisheries and the question of natural mortality have attracted too little attention in the participating countries so far.

The immense increase in the price of glass eel has raised questions on the cost-effectiveness of stocking, noting the very long investment period (10 years) and the open boundaries of most fishing areas (Section 2.5).

Tagging studies in the Baltic have provided some evidence that restocked foreign eel may differ from natural immigrants in their ability to find their way back to the breeding grounds and hence their contribution to the spawning stock (Westin, 1990). The basis is unknown and presents an important challenge that may be related to genetics or navigational imprinting or both.

4.4.3.3 Analytical research integrating existing knowledge

The eel is an adaptable and ubiquitous species, with ecologically distinct life stages and a wide geographical distribution. The extremely small pixel size that makes up the overall picture of the species in Europe has been stressed several times and the consequences for management, monitoring and research have been discussed. Observational studies are necessarily related to the lowest geographical level, the eel population in a local water body.

At the international level and, independently, at the level of general ecosystem analysis, there can be no lasting interest for individual pixels. The identification of global trends as well as ecological constraints in general must be sought. Integrating studies so far have failed because of the mismatch between the responsibilities of the financing parties and the goals aimed at. The compilation of supra-national studies as well as the integration of eel in broader ecological studies requires international concerted actions. Since this concerted action is a condition sine qua non for national research bodies, it provides the international manager the opportunity to achieve cost-effective integrative studies in close co-operation with research run by governments.

4.4.3.4 Analytical research related to the large scale of the life cycle of the eel

Eel reproduce in the Sargasso Sea area, but the precise location is still *mare incognitum.* The recent downward trends in recruitment have raised serious concerns about the spawning stock size. Because of the sheer size of the potential area where the true spawning location might be found, no analytical research has been undertaken for nearly 20 years. Even these efforts did little more than increase the precision of the discoveries of Schmidt in the first quarter of the 20th century.

Although concern about the size of the spawning stock was shared by the EIFAC/ICES Working Party On Eel at its 1996 meeting in IJmuiden (Netherlands), no scientific advice about the need for fisheries restriction could be provided. Until analytical research addressing the reproduction problem is undertaken in the long run, management advice will remain speculative. Should the current poor recruitment continue or deteriorate further and even if it improves and a subsequent failure occurs, scientifically based advice on this aspect will remain inadequate. Taking into account the costs of ocean-wide research programmes, analytical research concerning the reproduction can only be based on a long-term research plan, executed at an international scale.

The impact of aquaculture on the wild stock of eel has shown a sharp increase during the term of the Concerted Action. In the European setting, aquaculture has often been integrated in the management of the wild stock, for instance in the use of pregrown elver for stocking outdoor waters. However, the use of glass eel for aquaculture in eastern Asia has changed the impact dramatically: glass eel are removed from the wild population, to be grown in man-controlled systems in eastern Asia, without any being returned to the wild population. This removal severely threatens the wild stocks. Attempts to induce artificial reproduction have failed at the young larval stage. Knowledge of the natural reproduction process at sea might provide clues to the key factors related to maturation. In the end, this might result in successful artificial reproduction, uncoupling the commercial exploitation of eel culture and the conservation of the wild stock.

4.5 Implementation of this monitoring and research plan

This report has highlighted the importance of the eel stock as an international, marine derived resource which is of the highest biological and commercial value in its continental life stages. A baseline for monitoring and research related to international management is outlined. Implementation of this baseline requires working up of the required geographical, temporal and statistical detail, including aspects of methodology, data collection and processing, co-ordination and communication to management. Although the route to be taken is evident, details of the programme cannot be finalised at this stage. Co-ordination and synchronisation between managers at the national and international level on the one hand and scientists working on the common eel stock on the other, should have first priority. The elaboration of a detailed plan of action will then be a straightforward task for the eel workers involved.

In preparation for that synchronisation, the following considerations with respect to management level are paramount:

4.5.1 *Monitoring projects* related to international management will make a major contribution to local management. Co-financing by national and international parties is the most obvious structure here. The total manpower currently involved in eel management-related research and monitoring is estimated to be 19 man-years. Full implementation of the international monitoring scheme will require an additional 10 man-years.

4.5.2 *Baseline survey*. All of the work under this heading will be done at national level. The results will in due course be analysed at international level, but most nations will also benefit immediately from the collation of information above the regional scale. Therefore, the subsidiarity principle indicates a major share of national funding. Costs are estimated at 2 man-years per country over a 2-year period, with the exception of France and Italy, which will require double this input, because of the size of these countries and their intensive eel culture and fisheries.

4.5.3 *Methodological research* on monitoring is inherently linked with the monitoring itself. The route proposed here, essentially starts off from the national level, integrating existing knowledge in special Working Party meetings, concentrating on documentation of the methodologies used and their inter-calibration. International involvement is needed only to steer the national efforts towards the common goal, as by a Concerted Action structure.

4.5.4 *Analytical research* can seldom be cost-effective on a national basis, because of the great temporal and spatial scales involved and the limited application of the resulting knowledge within single countries. However, conducting parallel lines of research on all aspects of the biology of the eel within every single country is obviously not cost-effective. Therefore, a co-ordinated sharing of research effort between national Institutes is the only means of achieving the final goals. A Shared Cost status will reflect both the common goal and local work.

4.5.5 *Breeding*. Although all parties have a long-term interest in the common breeding stock, without international initiatives none of the countries will undertake any research of appreciable size related to the breeding problem. Therefore, international involvement is a prerequisite for support by national governments. Because of this special structure and the sheer size of the problem and field area, a dedicated implementation will be needed.

4.6 Conclusion

The eel qualifies as a single, highly migratory fish stock, found in all European waters. The requirements for monitoring and research implied by this status have been outlined in this chapter.

Essential monitoring should reflect the highly migratory status of the eel while covering the scattered distribution area in continental waters and the wide range of fishing techniques on different life stages throughout the continent.

The analytical basis for management is relatively weak; future research should first concentrate on the proposed management actions. Research co-ordinated between countries will be most cost-effective.

Until a long-term research programme is instituted to address the still unknown reproduction process and oceanic stages of the eel, future management advice on the status of the whole stock will remain speculative.

5. MANAGEMENT PLAN

It is clear from the foregoing chapters that, although many phases of the eel fishery may be managed within countries, the eel is a shared marine resource and must be treated as such. Management-related information on stocks, recruitment and population dynamics is seriously limited when compared with that relating to a number of the most valuable marine fish. In spite of this, the data gathered in the course of the concerted action are sufficient to compile a provisional management plan for the species.

Chapter 3.5 considers the available management tools. This chapter summarises the case for international action, presents a list of options ranging from extreme measures to complete inaction, followed by a table of the national priorities. The chapter ends with a recommendation for international action.

5.1 The case for international management measures

The Country Reports have shown that there are very large areas of water, marine, fresh and saline, in which unexploited stocks of eel exist. In addition, an escapement of 595 t of silver eel has been estimated from the small proportion of eel fisheries in which this stage is exploited and for which data are obtainable. The actual figure for escapement must be very much greater. There is little evidence one way or the other of whether the spawning stock biomass is sufficient. No scientific case can therefore be made for further restrictions on any fishery, nor can it be assumed that fishing mortality has no effect on spawning stocks. Therefore, the goal of improved management by increased distribution of glass eel must remain a priority because it serves both to enhance the fishery and to contribute to the spawning stock.

However, in the absence of uniform and obligatory control measures, rapid changes in the international markets for eel as observed in the past 2 years, form a serious risk. Therefore, it is of the utmost importance to establish procedures at the international level to prevent deterioration of the current situation and to enable rapid intervention when monitoring studies indicate the need.

The proven fall in recruitment to yellow eel habitat in all countries, however, has led to serious reductions in yield in all but a very small number of managed fisheries which depend on stock enhancement. The falling yield has been accompanied both by reduced employment for fishermen and by reduced supplies of wild eel to processing industries. The latter may have been replaced to some extent by increasing availability of intensively cultured eel.

The consequent unemployment and social disruption cannot be quantified in the absence of historical data on the size of the labour force in the past. But the overall socio-economic value of eel fisheries is high over a large part of the eel's range in Europe.

All the depleted bootlace, yellow and silver eel fisheries can be restored by stocking. The central problem lies in the fact that the majority of these fisheries are in countries which have no access within their boundaries to substantial untapped sources of glass eel. In three countries, Spain, Portugal and Great Britain, glass eel are the primary target species and fisheries for yellow and silver eel are of secondary importance. In a fourth, France, glass eel are the target on the Atlantic coast and yellow eel in Mediterranean regions. Decline of the fishery for yellow and silver eel in the other countries is largely explained by the fall in recruitment.

Because of the relative scarcity of glass eel and the unprecedented demand by aquaculture, particularly the rapidly developing industry in the Far East, the prices paid to glass eel fishermen are so high that they have led to serious reductions in the quantities available to national governments or fishery associations for stocking of open waters. This exacerbates the under-recruitment problems of the majority of yellow and silver eel fisheries.

In simple terms of maximising the income made from the sale of eel, market forces could be allowed to prevail to the benefit of the glass eel fishermen on the Atlantic coasts. However, from the point of view of the European economy, the cost in social and economic terms of further decline of the eel fishing industry in rural areas must be taken into account. The concerted action has shown that this decline is inevitable in the absence of greatly improved management.

Management of the eel fisheries on a Europe-wide scale requires that steps be taken to ensure that the distribution of glass eel from the Atlantic sources to depleted fisheries in other countries may be maintained or enhanced. There is strong circumstantial evidence that, even with the prevailing low recruitment, the carrying capacity of the habitat for feeding and growing eel associated with the glass eel fisheries is often exceeded. The glass eel removed from these waters for direct consumption or aquaculture could certainly not have lived within the catchments where they were captured. Should the fishery be closed or restricted, most of them would not survive to provide a catch of yellow or silver eel or to contribute to the spawning escapement. The ideal of Europe-wide management is to redistribute a proportion of this glass eel catch for the benefit of the depleted yellow and silver eel fisheries in other catchments.

5.2 Management options

The options given in summary in this section range from stringent conservation measures to a state of *laissez faire*.

5.2.1 Glass eel fisheries

5.2.1.1 Stop all fishing

This would cause extreme social hardship and could not be justified because, even in the absence of conclusive data, there is reason to believe that, in place of fishing mortality, extremely high natural mortality would occur in catchments with major glass eel stocks.

5.2.1.2 Restrict fishing

Maintenance of current fisheries is recommended on the precautionary principle. This requires strengthening of the management procedures. Further restrictions should not be imposed unless studies of natural mortality show that the glass eel fishery has a significant negative effect on the production of spawners.

5.2.1.3 Use levies on glass eel fishing to subsidise restocking programme

A levy payable by exporters and Aquaculturists may be justified on the grounds that they remove potential spawners from the population and that they themselves are dependent on the survival of the wild stocks. Alternatively, an agreed proportion of all glass eel caught could be diverted to stocking for the mutual benefit of fishermen and Aquaculturists alike.

5.2.1.4 Use all glass eel for restocking

The data in Table 3.2 show that the entire glass eel catch is required for stocking to attain the full potential of the wild eel fishery and to enhance the spawning escapement. Its use in this way would, however, destroy the eel aquaculture industry.

5.2.1.5 Do nothing

If no steps are taken, current market trends are likely to render uneconomical the majority of capture fisheries and all European intensive eel culture, while the increasing demands for glass eel may threaten the future spawning stock biomass.

5.2.2 Yellow and silver eel fisheries

5.2.2.1 Stop all fishing

Extreme social hardship would result, although cessation of fishing is likely to lead to an increase in spawning escapement. In the absence of clear evidence that fishing is a major cause of recruitment failure, this could not be justified.

5.2.2.2 Restrict fishing to protect spawning escapement

Restrictions are desirable in fisheries whose decline can be attributed to growth over-fishing and would in most cases benefit the fishermen in the medium-term by increasing the yield of larger eel and in the long-term by increasing spawning escapement. Additionally, existing spawner escapement should be ensured by legislation.

5.2.2.3 Enhance the existing international stocking operation

A stocking operation, developed from 5.2.1.3 above, is the most positive option to help halt the decline in the fisheries and enhance spawner escapement.

5.2.2.4 Solve catchment or national problems within their own areas

Local actions (e.g. fishery controls, trap-and-transport stocking, passes) can be beneficial. However, in many cases these are not possible, because local recruitment is too small to provide stocks for the catchments. Import of recruits is essential to halt the decline of such fisheries.

5.2.2.5 Do nothing

Some fisheries will be maintained by the exercise of current management measures, but the downward trend is likely to persist in many. The spawning stock might be endangered by rapid increases in the fishing pressure, stimulated by rising demands.

5.3 National management priorities

The table below summarises the main problem areas within countries. The low recruitment is, on the one hand, a universal problem but on the other the supply of glass eel locally available is simply not sufficient to restore depleted fisheries. In many cases it is possible, by reorganising the capture and release industry, to sustain levels of yield for consumption and of added spawner escapement. This is a first priority in all participating countries.

	Priority area	*National problems*	*Remedial measures*
Denmark	(1) Coastal water, fjord and freshwater: redevelopment of fishery (2) Maintenance of intensive culture	(1) Insufficient stocking material obtainable within country (2) High cost of stocking material	(1) Importation from England, France and Portugal (2) Subsidise supply
Sweden	(1) Maintenance and development of the fishery in the Baltic and lakes (2) Maintenance of intensive culture	(1) Insufficient stocking material obtainable within country (2) High cost of stocking material	(1) Transfers within country, importation from England, France and Portugal (2) Subsidise supply for stocking
Ireland (NI)	Lake fishery development	Insufficient stocking material	Develop glass eel/elver fishery, Importation from Great Britain
Ireland (Rep)	Lake fishery development	Insufficient stocking material	Develop glass eel/elver fishery
Great Britain	River and estuarine fishery development	High cost of stocking material	Improve management of glass eel/elver fisheries
Netherlands	Maintenance of IJsselmeer fishery, redevelopment of inland fisheries	Over-fishing, insufficient stocking material obtainable within country	Improved control, importation from England, France and Portugal
France	(1) Development of capture of live glass eel; (2) Restoration of depleted lagoon fisheries	(1) Unprecedented demand (2) Habitat loss, reduced recruitment	(1) Measures to ensure escapement (2) Subsidised transfers within country
Germany	(1) Redevelopment of coastal fishery (2) Maintenance of intensive culture	(1) Insufficient stocking material (2) High cost of stocking material	(1 & 2) Subsidised importation of glass eel
Spain	Development of capture of live glass eel.	Unprecedented demand	Measures to ensure escapement
Portugal	(1) Development of capture of live glass eel; (2) Maintenance of lagoon fishery	(1) Unprecedented demand (2) Growth overfishing	(1) Measures to ensure escapement (2) Transfers within country
Italy	(1) Restoration of depleted lagoon fisheries (2) Maintenance of lake fisheries (3) Maintenance of intensive culture	(1 & 2) Insufficient stocking material (3) High cost of stocking material	(1, 2 & 3) Subsidised importation of glass eel and bootlace eel

5.4 Maintenance and enhancement of yellow eel stocks

The highest densities of yellow eel are observed in coastal lagoons and in the lower reaches of river and lake systems. Yellow eel stocks in many habitats are naturally small or have been reduced by a number of factors, of which the following five may be ameliorated by the application of established management techniques:

5.4.1 Stocks naturally numerically small because of distance of habitat from the sea

Management requires stocking at rates to obtain optimum biomass by ensuring maximisation of use of the habitat without inducing growth retardation from over-crowding. A stocking rate of 0.1 kg of glass eel ha^{-1} is recommended as an overall figure. It is likely that more effective use of the available glass eel is made when they are artificially grown to the bootlace stage on the assumption that natural mortality of the bootlace eel is substantially lower than that of the glass eel following release.

5.4.2 Stocks reduced by natural recruitment failure

The programme operated by Denmark, Sweden, Germany and the Netherlands for the within-catchment transfer of stocking material and importation of glass eel from other (mostly more southern) countries should be maintained or enhanced. Mediterranean coastal lagoons also require introduction of glass eel from other catchments.

5.4.3 Stocks substantial but size of eel small due to growth overfishing

The precautionary principle requires that new developments should be permitted only in cases where it can be shown that stocking material for enhancement has been diverted from the direct consumption market and therefore does not represent reduction of spawning escapement.

5.4.4 Stocks reduced by emplacement of barriers with inadequate fish passes

Installation or improvement of fish passes, as appropriate, leads to enhanced survival and consequently to increase in fishing yields and spawning escapement.

5.4.5 Stocks reduced by environmental changes

In cases of occasional mortality caused by eutrophication, the management recommendation is to continue or enhance stocking as it is usual for eel to grow satisfactorily between crisis periods. Habitat restoration or improvements may be beneficial locally or regionally.

5.5 Estimates of costs of remedial measures

The initial reckoning is that an increase from the current 9,000 t to 60,000 t could be obtained in annual yield of yellow eel in the areas studied in this report. At 6 ECU per kg, the value of the increased catch would be 360 M ECU.

The cost of the 650 t of glass eel required for stocking at the current price of 125 ECU per kg is 80 M ECU. This appears to be a very worthwhile effort. Not included in the calculation are the value-added for the processing of the yellow and silver eel and the cost of handling the glass eel.

5.6 Implementation of the management plan

In *Report 1* the Concerted Action has gathered the available data on the current state of the stocks of the European eel and likely future developments. This report presents the relevant scientific information on which progress in management may be based. The implementation of the plan is an administrative matter with serious international implications and therefore outside the competence of the members of the Concerted Action.

It must be stressed that sufficient recruit material exists in Europe to develop and enhance the fishery *while at the same time increasing the spawning stock biomass.* Sufficient information has been gathered to indicate management priorities but development of a monitoring system and a greater research input – as described in Chapter 4 – are urgently required so that the cost effectiveness of the implementation of the management measures may be maximised.

In view of the rapidly changing situation, brought on by the unprecedented demand for glass eel, the Concerted Action considers that appropriate international action is a matter of urgency for social and economic reasons.

5.7 International management priorities

5.7.1 Market control of glass eel

The development of a major export demand and the consequent high prices for glass eel are threatening the very existence of stocking programmes already in progress. Unless addressed as a matter of urgency, they are likely to prohibit any significant moves towards realising the full potential of European waters as a source of eel and could lead to an increasingly rapid decline of the capture fisheries for yellow and silver eel. Consideration of ways and means of maintaining an adequate supply of glass eel for Europe should be given the highest priority.

5.7.2 Baseline survey and monitoring programme

The Concerted Action has compiled all available information of relevance on fisheries and biology and has concluded that this is far from sufficient for the requirements of fully effective management of the stocks. Implementation of co-ordinated one-off national surveys and of an internationally integrated monitoring programme to be determined by reference to their results is the next most urgently required measure.

5.7.3 Distribution of stocking material

The Concerted Action has shown that sufficient glass eel are currently captured to provide the stocking material required for three objectives: (a) to prevent further depletion of the capture fishery, (b) to restore or enhance the depleted continental stocks, (c) to increase the spawning escapement. Following the completion of the baseline survey advocated in Section 5.7.2, an international group, similar to the Concerted Action, should be convened to formulate a very much more specific and detailed series of recommendations for the rational use of the available stocking material.

5.7.4 Establishment of standard management procedures

Because of the scattered nature of the eel stock and the lack of consistency of management procedures at national levels, it has taken considerable time to realise that the total eel stock is under severe stress. Establishment of procedures for monitoring, management decisions and implementation is a prerequisite to rational management of the stock.

REFERENCES

Aprahamian, M.W. (1988) Age structure of eel, *Anguilla anguilla* (L.), populations in the River Severn, England, and the River Dee, Wales. *Aquaculture and Fisheries Management* 19, 365–376.

Ask, L. and L. Erichsen (1976) Blankelsmdrkningar vid svenska Vstersjvkusten 1941–1968. *Meddelande Havsfiskelaboratoriet Lysekil* 199: 1–117 (in Swedish).

Berg S. (1990) The assessment of size-class proportions and fisheries mortality of eel using various catching equipment. *International Revue der Gesamten Hydrobiologie* 75, 775–780.

Berg S. and J. Jorgensen (1994) Stocking experiments with 0^+ eel (*Anguilla anguilla*) in Danish streams: post-stocking movements, densities and mortality. In: I.G. Cowx (ed.) *Rehabilitation of Freshwater Fisheries.* Fishing News Books, Oxford, pp. 314–325.

Boetius I. and J. Boetius (1980) Studies of the European eel, *Anguilla anguilla*. Estimates of fecundity and energy reserves for migration and spawning. *Dana* 1, 1–28.

Callaghan R.M. and T. K. McCarthy (1991) Variations in population structure and growth of eel in the river Dunkellin system, Western Ireland. *EIFAC Working Party on Eel*, Dublin 1991.

Castelnaud G., D. Guerault, Y. Desaunay and P. Elie (1994) Production et abondance de la civelle en France au debut des annes 1990. *Bulletin Francais de Peche et Pisciculture* 335, 263–287

Castonguay M., P. V. Hodson, C. Moriarty, K. F. Drinkwater and T. Jessop (1994) Is there a role of ocean environment in American and European eel decline? *Fisheries Oceanography* 3, 197–203.

Churchward A.S. (1996) Overview of the Severn eel fishery, *EIFAC/ICES Working Group on Eel*, IJmuiden, Netherlands 1996.

Ciccoti, E. (1997). Italy *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 87-96.

Colombo G. and G. Grandi (1996) Histological study of the development and sex differentiation of the gonads in the European eel. *Journal of Fish Biology* 48, 493–512.

Costa J.L., Almeida P.R., C. A. Assis, F. M. Moreira and M. J. Costa (1991) A study of methods of estimating the size of eel populations in small streams. *Irish Fisheries Investigations* Series A 36, 68–69.

Deelder C.L. (1984) Synopsis of biological data on the eel. *FAO Fisheries Synopsis* 80. FAO, Rome, 87 pp.

Degerman E., J.-E. Fogelgren, b. Tengelin and E. Thornelof (1986) Occurrence of salmonid parr and eel in relation to water quality in small streams on the west coast of Scotland. *Water, Air and Soil Pollution* 30, 665–671

Dekker, W. (1996a) Long-term trends in the glass eel immigrating at Den Oever, the Netherlands. *EIFAC/ICES Working Group on Eel* IJmuiden, Netherlands 1996.

Dekker, W. (1996b) A length structured matrix population model, used as fish stock assessment tool. In: I.G. Cowx (ed.) *Stock Assessment in Inland Fisheries.* Fishing News Books, Oxford.

Dekker, W. (1997). Netherlands *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 70-73.

Dill, W. A. (1990). Inland Fisheries of Europe. *EIFAC Technical Paper* 52, pp 471.

Dill, W. A. (1993). Inland Fisheries of Europe. *EIFAC Technical Paper* 52 suppl., pp281.

Donnelly R.E., J.D. Reynolds and T. Walsh T. (1993) The management of glass eel stocks in the Shannon Estuary, Ireland. *EIFAC Working Party on Eel*, Olsztyn 1993. EIFAC, FAO, Rome, 23 pp.

Elie P., I. Cantrelle and N. Charlon (1982) Definition des limites differents stades pigmentaires durant la phase civelle d'*Anguilla anguilla* (L.). *Vie et Milieu* 3, 149–157.

G. Fontenelle, E. Feunteun and C. Briand (1997). France *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 74-79.

E. Hahlbeck and H. Kuhlmann (1997) Germany *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 54-56.

Hussein S.A. (1981) The population density, growth and food of eel *Anguilla anguilla* L. in some tributaries of the River Tweed. *Proceedings of the 2nd British Freshwater Fisheries Conference, University of Liverpool*, pp. 120–128.

Hvidsten N.R. (1985) Yield of silver eel and factors affecting downstream migration in the stream Emsa, Norway. *Report of the Institute of Freshwater Research*, Drottningholm, 62, 75–85.

Ibbotson A., P. Armitage, W. Beaumont, M. Ladle and S. Welton (1994) Spatial and temporal distribution of fish in a small lowland stream. *Fisheries Management and Ecology* 1, 143–156.

Kennedy G.J.A. and K.U. Vickers, (1993) The fish of Lough Neagh. Part A. A historical and taxonomic perspective of the fish fauna of the Lough Neagh catchment. In: R.B. Wood and R.V. Smith (eds). *Lough Neagh: the Ecology of a Multipurpose Water Resource*, Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 381–395.

Klein Breteler J. (1994) Stockings of pre-winter and post-winter glass eel and of elver from aquaculture: growth and survival in mesocosms. *EIFAC/ICES Working Group on Eel*, Oviedo, Spain 1994.

Knights, B. (1997) Risk assessment and management of contamination of eel (*Anguilla* spp.) by persistent xenobiotic organochlorine compounds. *Chemistry and Ecology* 14 (3).

Knights B. and E. White (1997a) An appraisal of stocking strategies for the European eel, *Anguilla anguilla* L. In: I.G. Cowx (ed.) *Stocking and Introduction of Fish.* Fishing News Books, Oxford..

Knights, B. and E. M. White, (1997b) Enhancing immigration and recruitment of eel: the use of passes and associated trapping systems. *Fisheries Management and Ecology* (submitted).

Knights B., E. White and I. A. Naismith (1996) Stock assessment of European eel, *Anguilla anguilla* L. In: I.G. Cowx (ed.) *Stock Assessment in Inland Fisheries.*Fishing News Books, Oxford, pp. 431–447.

Larsson P., S. Hamrin and L. Okla (1990) Fat content as a factor inducing migratory behaviour in the eel (*Anguilla anguilla* L.) to the Sargasso Sea. *Naturwissenschaften* 77, 488–490.

Leopold M. (1980) Some remarks on eel management in lakes. *Aquaculture* 19, 97–101.

Leopold M. (1986) Problems in analysing the effectiveness of eel stocking in interconnected lakes. *Vie et Milieu* 36, 291–293.

Leopold M. and M. Bninska (1984) The effectiveness of eel stocking in Polish lakes. In: *EIFAC Technical Paper 42/Supplement* 1, 41–49.

Lobon-Cervia J., Y. Bernat and P. A. Rincon (1990) Effects of eel (*Anguilla anguilla* L.) removals from selected sites of a stream on its subsequent densities. *Hydrobiologia* 206, 207–216.

Mann R.H.K. (1995) *Eel stock assessment in the UK.* Report to MAFF, Project No. SF0305, IFE Project No. T11063al. London: Ministry of Agriculture, Fisheries and Food. 86 pp.

Mann R.H.K. and J. H. Blackburn (1991) The biology of the eel *Anguilla anguilla* (L.) in an English chalk stream and interactions with juvenile trout *Salmo trutta* L. and salmon *Salmo salar* L. *Hydrobiologia* 218, 65–76.

Mann R.H.K. and T. Penczak (1994) The efficiency of a new electro-fishing technique in determining fish numbers in a large river in central Poland. *Journal of Fish Biology* 24, 173–185.

McCarthy T. K., J. Allison, R. Callaghan, P. Purcell and L. Copley (1994a) *Yellow eel stocks in the River Shannon and the development of a fyke net fishery.* Report to Electricity Supply Board, Dublin, Ireland.

McCarthy T.K., K. Cullen, K. Faherty and M. M. O'Farrell (1994b) *River Shannon silver eel: Population biology, factors influencing downstream migration and commercial fishing.* Report to the Electricity Supply Board, Dublin, Ireland.

Moriarty C. (1984) Stock enhancement in Irish eel *Anguilla anguilla* (L.) fisheries. *EIFAC Technical Paper 42/Supplement* 1, 50–57.

Moriarty C. (1986) Riverine migration of young eel *Anguilla anguilla* (L.) *Fisheries Research* 4, 43–58.

Moriarty C. (1987) Eel stocks of the Shannon system and prospects for development. *Fishery Leaflet* 139. Dublin, Ireland, 15 pp.

Moriarty C. (1990a) European catches of elver 1928–1988. *International Revue Gestalt Hydrobiologie* 75, 701–706.

Moriarty C. (1990b) Eel stocks, capture and culture. In: K.T. O'Grady, A.J.B. Butterworth, P.B. Spillett, and J.C.J Domaniewski (eds.). Fisheries in the Year 2000. *Proceedings of the 21st Anniversary Conference of the Institute of Fisheries Management.*

Moriarty, C. (1990c) Eel management practices in three lake systems in Ireland. In: W.L.T. van Densen, B. Steinmetz and R.H Hughes (eds.). *Management of Freshwater Fisheries.* Pudoc, Wageningen, Netherlands, pp. 262–269.

Moriarty C. (1996a) The European eel fishery in 1993 and 1994. *Fisheries Bulletin (Dublin)* 14.

Moriarty C. (1996b) Glass eel supply and demand in Europe in 1995 and 1996. *EIFAC/ICES Working Group on Eel* Ijmuiden, Netherlands.

Moriarty, C. (ed.) (1997) The European eel fishery in 1993 and 194: First Report of a working group funded by the European Union Concerted Action AIR A94-1939. *Fisheries Bulletin (Dublin)* 14 (1996), 52 pp.

Moriarty C. and e. Nixon (1990) Eel biomass in a small lowland stream. *International Revue der Gesamten Hydrobiologie* 75, 781–784.

Moriarty, C. and J. Reynolds (1997) Ireland *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 61-65.

Moriarty C. and F.-W. Tesch (1997) Possible increase in catch of Atlantic elver in 1993 and 1994. *Ecology of Freshwater Fish* 5, 213-215

Moriarty C., M. Bninska and M. Leopold (1990) Eel, *Anguilla anguilla* (L.), stock and yield in Polish lakes. *Aquaculture and Fisheries Management* 21, 347–356.

Mortensen E. (1982) Production of trout *Salmo trutta* in a Danish stream. *Environmental Biology of Fishes* 7, 349–356.

Naismith I.A. and B. Knights (1988) Migrations of elver and juvenile European eel, *Anguilla anguilla* L., in the River Thames. *Journal of Fish Biology* 33(Supplement A), 161–175.

Naismith I.A. and B. Knights (1990a). Studies of sampling methods and of techniques for estimating populations of eel, *Anguilla anguilla* L. *Aquaculture and Fisheries Management.* 21, 357–367.

Naismith I.A. and B. Knights (1990b) Modelling of unexploited and exploited populations of eel, *Anguilla anguilla* (L.), in the Thames Estuary. *Journal of Fish Biology* 37, 975–986.

Naismith I.A. and B. Knights (1993) The distribution, density and growth of European eel, *Anguilla anguilla* L., in the River Thames catchment. *Journal of Fish Biology*, 42, 217–226.

Naismith I.A. and B. Knights (1994) Fyke-netting and coarse fisheries in lowland Britain: practical advice for fishery owners and managers. *Fisheries Management and Ecology* 1, 107–116.

Neveu A. (1981) Densitie et microrepartition des differentes especes de poissons dans la Basse Nivelle, petit fleuve cotier des Pyrenees Atlantiques. *Bulletin de Francais Pisciculture* 280, 86–103.

Nielsen J. (1988) A review of marking and tagging methods applied to eel. *EIFAC Occasional Publications* 21, 1–48.

NRA (1995) *The survival and dispersal of stocked coarse fish.* RandD Project Note 364. Bristol, England: National Rivers Authority (now the Environment Agency), 81 pp.

Parsons J., K. U. Vickers and Y. Warden (1977) Relationships between elver recruitment and changes in sex ratio of silver eel *Anguilla anguilla* L. migrating from Lough Neagh, Northern Ireland. *Journal of Fish Biology* 10, 211–229.

Pedersen, M. I. (1997) Denmark *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 50-53.

Poole W.R., J. D. Reynolds and C. Moriarty (1990) Observations on the silver eel migrations of the Burrishoole River system, Ireland. *International Revue der Gesamten Hydrobiologie* 75, 807–815.

Pursiainen M. and J. Toivenen (1984) The enhancement of eel stocks in Finland: A review of introductions and stockings. *EIFAC Technical Paper* 42/Supplement 1, 59–67.

Report 1 *see* Moriarty (1997).

Quigley D. and T. O'Brien (1993) The River Shannon eel fishery: A management review. *EIFAC Working Party on Eel*, Olsztyn, Poland 1993.

Rasmussen G. (1977) Production of eel in a small stream in Zealand. *Proceedings of the 8th British Coarse Fish Conference, University of Liverpool*, pp. 61–68.

Rasmussen G. (1983) Recent investigations of the population dynamics of eel (*Anguilla anguilla* L.) in some Danish streams. *Proceedings of the Third British Freshwater Fisheries Conference, University of Liverpool*, pp. 71–77.

Rasmussen G. and B. Therkildsen (1979) Food, growth and production of *Anguilla anguilla* L. in a small Danish stream. *Rapports et Proces-Verbaux des Reunions, Conseil International pour l'Exploration de Mer* 174, 115–123.

Rigaud C., G. Fontanelle, D. Gascuel and A. Legault (1988) *Le franchissement des ouvrages hydrauliques par les anguilles (*Anguilla anguilla*): Presentation des dispositifs installes en Europe.* Les Publications di Department d'Halieutique 9 France, ENSA de Rennes, 147 pp.

Rosell, R. (1997) Ireland (Northern Ireland) *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 57-60.

Rossi R. (1979) An estimate of the production of the eel population in the Valli of Commacchio (PO Delta) during 1974–1976. *Bollitino di Zoologia* 46, 217–223

Rossi R. and A. Cannas (1984) Eel fishing management in a hypersaline lagoon of southern Sardinia. *Fisheries Research* 2, 285–298.

Rossi R. and G. Colombo, (1976) Sex ratio, age and growth of silver eel in two brackish water lagoons in the northern Adriatic Valli of Commachio and Valli Nuova. *Archives of Oceanography and Limnology*, 18 (Supplement 3), 327–341.

Rossi R. and L. Corbari (1982) Biological analysis of the fish catch in the Acquitina lake (southwestern Adriatic Sea, Italy) for the 1976–9 period. *Memorie di Biologia Marina e di Oceanografia* 12, 115–133.

Rossi R. and P. Papas (1979) Analisi del pescato di una `valee' del Delta del Po (Valle Nuova) dal 1950 al 1978. *Annali Universite di Ferrara (Biologie I)* 9, 123–148.

Rossi R. and P. Villani (1980) A biological analysis of eel catches, *Anguilla anguilla* L., from lagoons of Lesina and Verano, Italy. *Journal of Fish Biology* 16, 413–423.

Rossi R., P. Carrieri and M. G. Rizzo (1988) Use of intensive rearing systems as back-up for coastal lagoon aquaculture: an experience with eel, *Anguilla anguilla* L., in the Commachio lagoons. *Aquaculture and Fisheries Management* 19, 355–361.

Rossi R., P. Carrieri, G. Franzoi, G. Cavallini and A. Gnes (1987–1988) A study of eel (*Anguilla anguilla* L.) population dynamics in the Commachio lagoons (Italy) by mark-recapture method. *Oebalia* 14, N.S.: 1–14.

Sers, B., E. Meyer and O. Enderlein (1993) Sammanstdllning av fiskmdrkningar utfvrda under eren 1980–85. *Information fren Svtvattenslaboratoriet, Drottningholm*, 4. 71 pp.

Svedang H, E. Neuman and H. Wickström (1996) Maturation patterns in female European eel: age and size at the silver eel stage. *Journal of Fish Biology* 48, 342–351.

Tesch F.-W. (1977) *The Eel: Biology and Management of Anguillid Eel.* Chapman and Hall, London.

Tulonen J. (1990) Growth and sex ratios of eel (*Anguilla anguilla*) of known age in four small lakes in southern Finland. *International Revue Gestalt Hydrobiologie* 75, 792–800.

Turnpenny, A.W.H. (1989) Field studies on fisheries in acid waters in the United Kingdom. In: Morris et al. (eds) Acid Toxicity and Aquatic Animals. *SEB Seminar Series* 34, 45–65.

Vøllestad L.A. (1992) Geographic variation in age and length at metamorphosis of maturing European eel: environmental effects and phenotypic plasticity. *Journal of Animal Ecology* 61, 41–48.

Vøllestad L.A. and B. Jonsson (1988). A 13-year study of the population dynamics and growth of the European eel *Anguilla anguilla* in a Norwegian river: evidence for density-dependent mortality and development of a model for predicting yield. *Journal of Animal Ecology* 57, 983–997.

Vøllestad L.A., R. Lecomte-Finger and B. Steinmetz (1988) Age determination of *Anguilla anguilla* and related species. *EIFAC Occasional Publications* 21, 1–28.

Westerberg H., J. Haamer and I. Lagenfelt (1993) A new method for sampling elver in the coastal zone. *ICES CM 1993*/M:5, 10 pp.

Westin, L., (1990) Orientation mechanisms in migrating European silver eel (*Anguilla anguilla*): temperature and olfaction. *Marine Biology* 106: 175–179.

White E.M. and B. Knights (1994) *Elver and eel stock assessment in the Severn and Avon*. RandD Project Record 256/13/ST. National Rivers Authority, Bristol, England, 141 pp.

White, E.M. and B. Knights (1997a) Dynamics of upstream migration of the European eel, *Anguilla anguilla* L., with special reference to the effects of man-made barriers. *Fisheries Management and Ecology* in press.

White, E.M. and B. Knights (1997b) Environmental factors affecting migration of the European eel, *Anguilla anguilla* L., in the Rivers Severn and Avon. *Journal of Fish Biology* 50, 1104-1116.

Wickström, H. (1984) The Swedish eel stocking programme. *EIFAC Technical Paper* 42/Supplement 1, 68–83.

Wickström, H. and S. Hamrin (1997). Sweden *in* Moriarty and Dekker (eds.) Management of the European eel. *Fisheries Bulletin (Dublin)* 15, 44-49.

Wickström H., L Westin and P. Clevestam (1996) The biological and economical yield from a long-term eel stocking experiment. *Ecology of Freshwater Fish* 5, 140–147.

Winfield I.J., C. M. Tobin and C. R. Montgomery (1993) The fish of Lough Neagh. Part E. Ecological studies of the fish community. In: R.B. Wood and R.V. Smith (eds). *Lough Neagh: the Ecology of a Multipurpose Water Resource*, Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 451–471.

ANNEX 1. COUNTRY REPORTS

The country reports present, in summary form, scientific papers and other information relevant to management planning for each of the participating countries.

Sweden	Håkan Wickström and Stellan Hamrin,
Denmark	Michael Pedersen
Germany	Eka Hahlbeck and Holmer Kuhlmann
Ireland (Northern)	Robert Rosell
Ireland (Republic)	Christopher Moriarty and Julian Reynolds
Great Britain	Brian Knights
Netherlands	Willem Dekker
France	Guy Fontenelle, Eric Feunteun and Cédric Briand
Portugal	Maria Assunção Santos
Spain	María José Lara
Italy	Eleonora Ciccotti

SWEDEN

Håkan Wickström and Stellan Hamrin
National Swedish Board of Fisheries, Institute of Freshwater Research, S-178 93 Drottningholm, Sweden.

Habitat

Extent of water currently supporting eel stocks

Estuaries Normally the *estuary concept* is not used in Sweden. Sometimes the whole Baltic, including the Danish Belts and Kattegat, is looked upon as an estuary (Westerberg, 1996). The mouth of the River Göta Älv situated on the west Coast could perhaps be considered a real estuary. There is an extensive eel fishery in that area, but as eel are, or at least were, abundant in all coastal areas this question is not really relevant. There are however no specific data on this issue.

Coastal lagoons There are no coastal lagoons in Sweden.

Lakes There are about 39,639 km^2 of freshwater lakes in Sweden. Of this about 17,570 km^2 seem suitable for eel production. It is estimated that about 11,074 km^2 today support eel stocks which, however, in most cases are extremely sparse. There are large parts of this area which do not support any local eel fishery at all, due to very sparse stocks, but on the national scale most of them will contribute to the commercial fishery in the large lakes and along the Baltic Coast. A more developed eel fishery takes place in about 4,921.4 km^2.

Coastal water Eel are present in most Swedish coastal waters, ranging from quite abundant along the west coast (8,600 km^2 with depths less than 20 m) to more and more scarce in the northern part of the Baltic Sea (25,500 km^2 with depths less than 10 m). The total area is thereby 34,100 km^2. There are commercial fisheries for eel up to about 60° N on the Baltic coast, so that eel fishing takes place in about 14,600 km^2 out of the available 25,500 km^2 along the Baltic coast.

Rivers/canals There are 118 main rivers in Sweden and some additional 5,763 rivers and streams of sufficient size to be registered with their own co-ordinates in the database of the Swedish Meteorological and Hydrological Institute. Total length of all 5,881 is about 79,153 km. Assuming a mean width of 10 m, this length represents an area of about 792 km^2. There are no data on how much of this is utilised by eel. However, there are no fisheries targeting eel in running water, except in small mill traps and some few fixed installations of the stow net type *ållana.*

Areas of water inaccessible to eel due to chemical or physical obstructions

Lakes In rivers where ascending eel are still fairly abundant there is normally some kind of eel pass or upstream transportation. In that way most areas of water are theoretically accessible for eel. However, in areas where recruiting eel have become naturally rather few in recent days such installations have often been forgotten and mismanaged leaving areas without eel. The extent of this is not known. Another possible *obstacle* to eel recruitment is low temperatures, low productivity and high altitudes in the northern parts of Sweden. Some parts of the largest lakes are too deep (>20 m) for eel. On account of this we estimate that 20,620 km^2 of our total lake area, i.e.. 52%, have no potential for eel production. Today physical obstacles, etc. are perhaps not the primary limitation of eel in Sweden. The general lack of recruits, especially in the Baltic part of the country, is probably much more important.

Rivers/Canals The same observations apply as in the preceding paragraph.

Data on stock and sustained or increased yield

Data from the Fisheries Officers of various County Administrative Boards together with the authors personal observations are given in Table 1.

Thorman and Fladvad (1981) investigated, among other fish species, the abundance, growth and production of young eel in the estuary of the River Broälven (north of Gothenburg on the Swedish west coast). The net annual production of 0+ and 1+ eel was estimated to be about 43 g m^{-2} in riverine areas. In the marine areas, production was much lower, between 0.06 and 0.69 g m^{-2}.

Westerberg has in several papers (e.g. Westerberg, 1994, 1996, Westerberg, et al 1993) given data on the abundance of small eels along the Swedish and the Danish coast in the vicinity of the Öresund. Typical values were 1 - 2 small eels m^{-2} in vegetation in shallow waters on the Swedish side and about 0.2 along the Danish side.

From extensive electrofishing investigations we know that during 1954–1979 eel were found in about 70% of all sites (below 100 m a.s.l) visited. During 1990–1995 the corresponding value had fallen to about 35%. Today eel are found in 10% of all stream sites investigated and where they occur the mean density is 9 eel 100 m^{-2}. From this electrofishing survey a fishing efficiency of 0.78 (p^3) was found (B. Sers, pers. comm.).

Table 1. Eel yield of Swedish lakes.

	Surface km ^{2}	Yield kg/ha	t	Trophic state	Years of data
L. Vanern	2,691	0.1	20	mainly oligotrophic	10
L Malaren	872	0.3	29	mainly mesotrophic	10
L Hjalmaren	484	0.5	22	meso-eutrophic	10
L Ymsen	15	3.4	5	eutrophic	1
L. Tjarnesjon	3	0.2	0	oligotrophic, acidified	11
L Ringsjon	41	2.7	0	eutrophic	3
L Vombsjon	12	7.4	0	eutrophic	3
L. A in Östergötland	94	0.7	11	eutrophic	22
L. Angen	2	0.4	0	mesotrophic	6
L Fardume Trask	3	1.2	0	oligo-mesotrophic	6
L. B in Östergötland	76	0.2	3	oligotrophic	22
L. Sommen	132	0.1	1	oligotrophic	1
L. Vigdan system	6	0.1	0	oligo-mesotrophic	11
Ten lakes in Scania	77	3.4	29	eutrophic	38

The occurrence of different fish species in lakes was investigated during the time period 1930–1950. Compared to the data derived from the most recent electrofishing surveys (in running waters) eel were much more common in those days. Large inland areas draining to the Baltic Sea are today devoid of eel (cf. Figs 1 and 2: B. Sers, pers. comm.).

Historical records of stocking

The recent long-term yield of 0.5 kg ha^{-1} in Lake Hjälmaren is based on an annual stocking rate of about 4.7 t of yellow eel, i.e. about 1.1 yellow eel (37 cm) ha^{-1}. The 10 Scania lakes of 77 km^2 with a yield of about 3.4 kg ha^{-1} are normally stocked annually with about 20 yellow eel of 37 cm per ha.

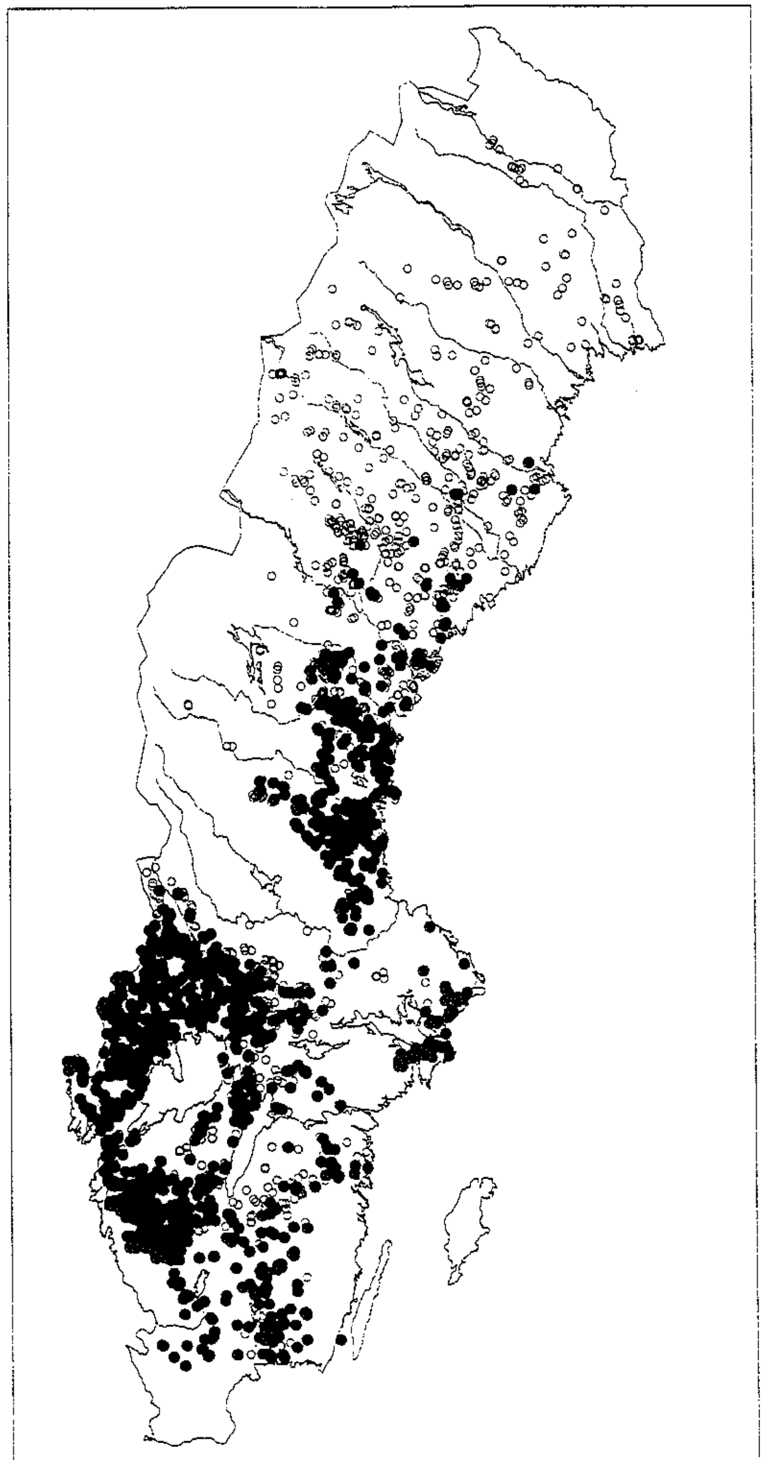
Table 2. Quantities of elver and yellow eel stocked.

	Yellow eel from Swedish west coast kg	**Imported elver** after quarantine numbers	**Miscellaneous** *Trollhätteål* numbers
1990	56,716	731,000	29,300
1991	60,780	339,900	57,600
1992	76,608	398,000	33,700
1993	64,725	625,000	14,900
1994	59,215	1,982,900	12,800
1995	39,605	1,664,060	0
1996	25,000	1,123,380	64,200
Total	**382,649**	**6,864,240**	**212,500**

A restocking programme was begun in Sweden in 1972. The stocking programme used three sources of eel (Table 2):

-Medium-sized yellow eel caught along the Swedish west coast, where eel were still quite abundant.
-Imported elver from France (Bay of Biscay) and subsequently from the UK (River Severn).
-The redistribution of young eel within the same river system.

Figure 1. Presence ● and absence O of eel in lakes in Sweden 1930 - 1950. (Swedish Lake Register, Institute of Freshwater Research, Drottningholm).



In Lake Hjälmaren about 74,866 kg of yellow eel were stocked between 1966 and 1995. This amount roughly corresponds to 823,526 eel. In addition to that some 200,000 elver were stocked in 1985. Corresponding data for Lake Mälaren are 177,587 kg or about 1,953,457 eel between 1984 and 1995. The numbers of elver were 2,003,750. In Lake Vänern 142,034 kg were stocked between 1966 and 1993. In addition some 1,847,000 elver and 2,220,100 natural recruits (from the eel ladder) were stocked between 1957 and 1995.

Data on population dynamics

Andersson et al. (1991) applied catch curve analyses (Ricker, 1975) to medium sized eel from three coastal localities on the Swedish west coast. The rate of decrease was 57%, 47% and 32% in the three populations, respectively, when passing from successive 5-cm length classes, very roughly corresponding to 1-year growth. This decrease was assumed to be the combined effect of natural mortality and migrations.

Svedäng (1996) has investigated the fishing and fishing pressure for yellow eel along the Swedish West Coast. From data on the age distribution of yellow eel from heavily exploited areas and from areas with a very low fishing pressure he calculated a natural instantaneous mortality of 0.18 for eel above 40 cm in length, including emigration (M+E). When applying this value to the exploited stocks he found the fishing instantaneous mortality to be approximately 0.27.

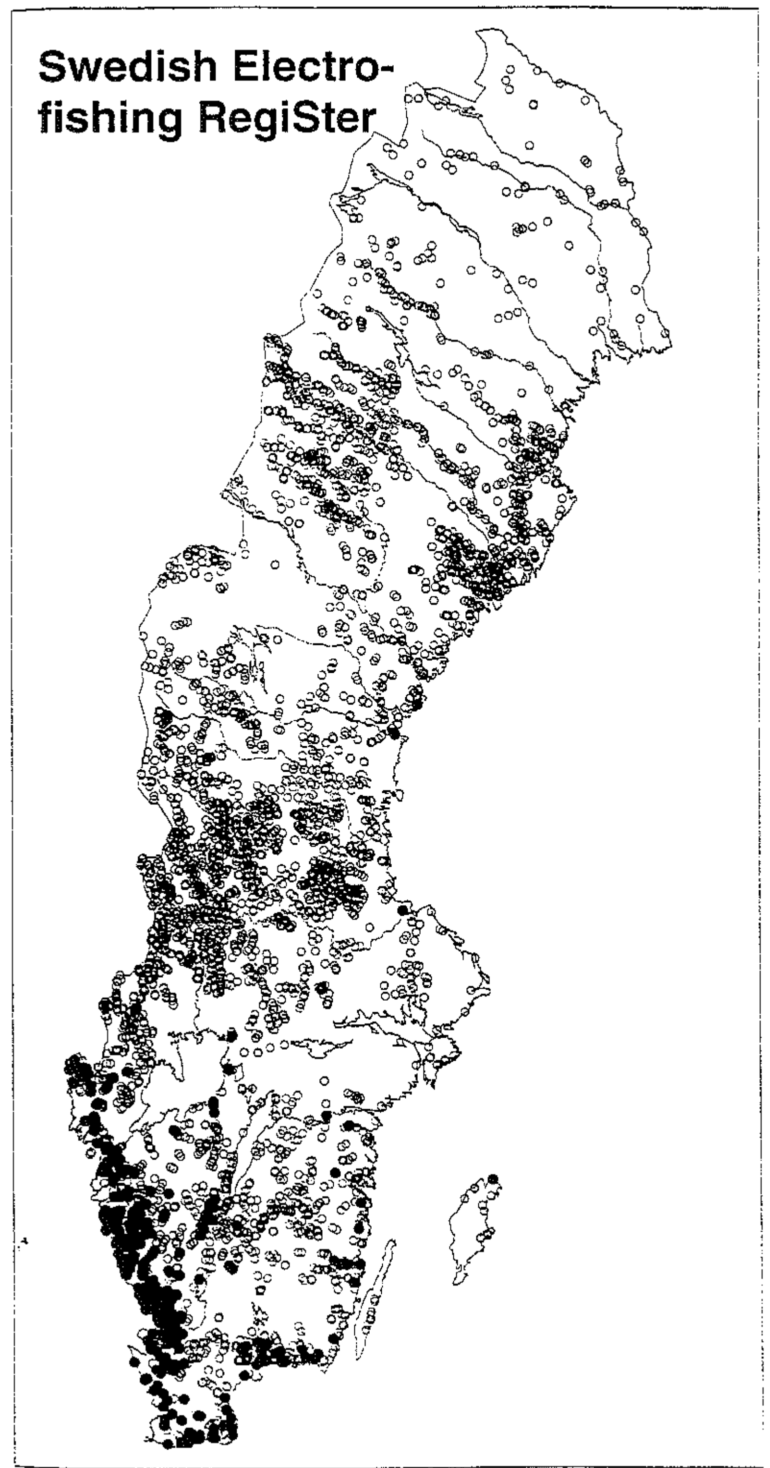
Recruitment

Natural mortality of glass eel

In a paper on the abundance of young eel (7–25 cm) representing three or four year classes along the Swedish west coast, Westerberg et al. (1993) showed that elver dominated (*ca.* 80%) in the inshore zone. The number of eel of the next year class was about 83% fewer, suggesting a combined effect of natural mortality and migration of about 80%, assuming that recruitment was the same in successive years.

Fishing mortality of glass eel

Figure 2. Presence ● and absence O of eel in streams in Sweden 1954-1996. (Swedish Electro-fishing Register, Institute of Freshwater Research, Drottningholm).



Glass eel or, more exactly, elver are caught in some rivers, including Göta älv, Viskan, Lagan, Mörrumsån and Motala Ström, for transfer to upstream regions.

Some calculations on the total recruitment to the Swedish west coast were made by Lindquist (1976) and Westerberg (1979). From Lindquist's data on the transport of glass eel to the Skagerak, Westerberg estimated the total recruitment to be about 5 million. From later studies with the drop-trap technique (described in Westerberg et al., 1993), Westerberg (1987) estimated the total number of 0+ recruits to be about 25 million.

Escapement of glass eel

Glass eel and elver are not exploited in Swedish rivers apart from the organised catch in traps at the most downstream dam for transfer and distribution upstream. This is valid also for larger young eel entering fresh water. Such activities are today taking place in about 20 rivers.

Data on survival of glass eel or bootlace eel after stocking

Westerberg (1987) discussed in a paper on a stocking experiment the losses of young eel and the proportion that was due to natural mortality. About 50% disappeared every year, considered to be mainly due to emigration. The natural mortality was estimated to be 10% at the most. southern Baltic, off the south coast of Sweden.

Mortality or, strictly speaking, minimum survival rates expressed as recapture rates were given by Andersson et al. (1991) and Wickström et al. (1996). In the first case, elver stocked in an open coastal area improved the local stock and, within 7 years, more than 3.5% were recaptured. The remaining 96.5% might be explained by natural mortality, dispersal and the fact that most eel were not fully recruited to the fishery in the course of the investigation. In the latter case, in which cultured bootlace eel were stocked in a closed freshwater system, about 11.3% (males and females together) were recaptured within 14 years. In simplified terms, 8.2% of the female eel stocked in this Lake Fardume Träsk were recaptured around 1992, after roughly 12 years in the lake. Thus, not more than 91.8% (100–8.2%) can have died within this period. This corresponds to a yearly *mortality* of about 18.5%.

As the cumulative recapture rate has not yet levelled out we assume there are many eel left to be recaptured in the future and therefore this *estimate of mortality* is very conservative. If the current trend in recapture continues for another 5 years the total recapture rate will reach 17%.

Rough calculations on data of average stocking densities and the corresponding yields from the lakes Vänern, Hjälmaren and the Scania lakes give 0.30, 0.45 and 0.17 kg, respectively, as yield per recruit.

The Board of Fisheries together with Statistics Sweden made a survey regarding the catch of sport fishermen and *household fishermen* in 1995. Responses on eel were relatively few, 125 out of 5,400 persons, and the standard deviations were high. Svedäng (1996b) mentions that a local study showed that non-professional fishermen made an eel catch equal to about 32% of the total commercial catch of eel.

In total, 1,273 t ± 301 of eel were said to be caught, mostly by longlines, 569 t ± 204, followed by fyke nets, 384 t ± 109. If this is accurate, the sport fishermen's catch is about the same as the commercial catch. Most of the longline catch was from the southern parts of the Baltic Sea and from *small lakes* – not the five largest. The catches by fyke net were mainly from the middle part of the Baltic (east coast) and from the

Data on economics of stocking

Wickström et al. (1996) reported a very good economical return from one stocking experiment. A shallow oligo-mesotrophic lake of 339 ha was stocked once with about 53,000 cultured eel of about 3 g each. Thus the stocking density was 156 eel ha^{-1} . The resulting stock was monitored for many years, mainly by catching descending silver eel in an outlet trap. The investment in stocking eel was repaid with interest after about 10 years and there were many years of yield left. Westerberg (1987) discussed the economic gains from eel stockings proposed for the Swedish west coast and found the return to be negative on a local scale. From a national perspective, however, having regard for the dispersal of stocked eel, the return should be almost twice the cost of investment plus interest.

Escapement

Escapement of silver eel

Tagging experiments have been in progress along the Swedish east coast, in the Baltic, for many years (Ask and Erichsen 1976; Westin, 1990; Sers et al., 1993). The primary aim has been to assess the disturbing effects of various effluents such as thermal discharges and effluents from industries such as paper mills, etc., on the migrating silver eel.

Ask and Erichsen (1976) reported on the recapture rates of silver eel tagged and released at different occasions and sites along the Baltic coast. Of a total of 16,882 silver eel 8,302 were recaptured, corresponding to 49.35%. The recapture rates from different experiments ranged between 69 and 76%. Sers et al. (1993) summarised the recapture rate of 2,403 silver eel tagged during 1980–1985 to be 35%. Westin (1990) found much lower recapture rates in his investigations, however the experiments were performed with silver eel previously stocked.

The tagged eel which were not recaptured in Sweden, Germany or Denmark are believed to be able to continue towards the spawning area without further fishing mortality.

Number and extent of unexploited water bodies

As the commercial fishery nowadays targets mainly large silver, and therefore female, eel, the few males appearing in Swedish waters are seldom exploited. Males are found mostly along the west coast where the unsheltered open water does not permit an effective fishery.

There are eel-producing waters such as large rivers with boat traffic and locks and also the open coast of the Kattegat and Skagerak where efficient fishing for silver eel is not feasible. All these regulations and situations make it possible for eel to avoid exploitation.

It might be possible to give the area of sea and from a number of rivers on the Swedish West Coast where an efficient fishing for silver eel is not possible. However the matter is complicated as the fishery for yellow eel is quite efficient along that coast. According to Svedäng (1996) the fishing mortality (F) for eel above 40 cm is about 0.27.

Information on conservation measures

There is no legislation in Sweden primarily aimed at the active conservation of the spawning stock of the eel. There are, however, minimum legal sizes in force in all coastal waters, in coastal streams up to the most downstream barrier (for salmonids) and in some freshwater lakes. This rule is quite recent (1994) and one result is that there are no minimum legal size limits in fresh water above this barrier. The five biggest lakes are excepted and require a 55 cm size. In some additional lakes the private fishery-owners have adopted the same 55 cm size. For the time being this new legislation means that elver and young eel above this barrier are no longer protected against exploitation.

The operation of fixed traps for eel and other species is prohibited by law during certain months of the year when smolts and salmon and trout are believed to descend the rivers. Normally a catching device is not allowed to close the full width of a river. According to very old regulations one-third to one-half has to be left open unless exemption has been granted.

Commercial capture of glass eel and elver is controlled by minimum size regulations, but young eel are often caught at the most downstream dam on a river system and then distributed in the watercourse upstream. The dam-owner is required to take such measures by the water law-court.

Since 1994 only licensed fishermen are allowed to use more than six fyke nets or pots. This legislation probably leads to a decreased catch from sport fishermen, etc. and thus the commercial statistics become more reliable.

References

Andersson J., Sandström O., and Hansen H.J.M. (1991) Elver (*Anguilla anguilla* L.) Stockings in a Swedish thermal effluent – recaptures, growth and body condition. *Journal of Applied Ichthyology* 7, 78–89.

Ask L. and Erichsen L. (1976) Blankålsmärkningar vid svenska Östersjökusten 1941–1968. *Meddelannde fran Havsfiskelaboratoriet Lysekil* 199, 1–117.

Edman G. (1995) Ålförekomst i Tjärnesjön, Falkenbergs Kommun. *Miljö- och Hälsoskyddskontoret Rapport 1995: 2 Falkenbergs Kommun*, 23 pp.

Ricker, W. E. (1975) Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada* 191, pp 328.

Lindquist A. (1976) Observations on glass eel in the Skagerak and Kattegat. *Meddelanden Havsfiskelab, Lysekil.* 201 7 p.

Sers B., Meyer E. and Enderlein O. (1993) Sammanställning av fiskmärkningar utförda under åren 1980–85. *Information från Sötvattenslaboratoriet*, Drottningholm, no 4, 71 p.

Svedäng H. (1996) *Kustlaboratoriets yttrande angående framställan om begränsning av antalet ålryssjor längs västkusten från Norra Bohusläns P O.*

Thorman, S. and B. Fladvad (1981). *Growth and production of fish in River Broälven Estuary on the Swedish west coast.* PM 1416, National Swedish Environmental Protection Board, pp 112..

Westerberg H. (1979) Elver in the thermal discharge of a nuclear power plant. *Information Fran Sötvattenslaboratoriet, Drottningholm* 7, pp 12.

Westerberg H. (1987) Utsättning av al pa vastkusten, del 3, Pa vastkusten samlas alen. *Yrkesfiskaren* 19–87, 8–9.

Westerberg, H. (1994) *Juvenil ål på grundområden i Öresunde. Baslinjestudie, statusrapport maj 1994.* Rapport 11, pp 11.

Westerberg H. (1996) Oceanographic aspects of the recruitment of eel to the Baltic Sea. *EIFAC/ICES Working Group on Eel*, IJmuiden, Netherlands, 1996.

Westerberg H., Haamer J. and Lagenfelt I. (1993) A new method for sampling elver in the coastal zone. *ICES CM 1993*/M:5, 10 p.

Westin, L. (1990). Orientation mechanisms in migrating European silver eel (Anguilla anguilla): temperature and olfaction. *Marine Biology* 106, 175-179.

Wickström H., Westin L. and Clevestam, P. (1996) The biological and economical yield from a long-term eel-stocking experiment. *Ecology of Freshwater Fish* 5, 140–147.

DENMARK

Michael Pedersen
Danish Institute for Fisheries Research, Inland Fisheries Laboratory, Vejlsøvej 39, DK-8600 Silkeborg, Denmark

Habitat

Extent of water currently supporting eel stocks

Estuaries The expression *semi-inland waters* is used to include fjords, estuaries, sheltered bays and lagoons covering some 3,000 km^2 which possibly have relatively large eel stocks compared to more open coastal waters.

Lakes There are about 500 freshwater lakes and ponds in Denmark covering a total area of about 430 km^2 and about 10 km^2 of reservoirs. Eel are believed to be present in most of these waters, either naturally recruited or stocked by landowners or local fishermen's organisations.

Rivers There are about 15,000 km of major rivers and streams. The total area including minor streams is 150 km^2. Eel have access to all streams and rivers because fish passes must be installed at any obstruction.

Coastal waters

Eel fishing takes place all along the Danish coasts. The only known area with no eel fishing is on the west coast of Jutland from the north tip down to the Wadden Sea. In the Wadden Sea, eel populations are present as they are on practically all other coasts. The area of coastal waters where eel stocks may be present is in the order of 10,000 km^2 of which 9% is considered to be part of the Baltic Sea.

Areas of water inaccessible to eel due to chemical or physical obstructions

Rivers/streams

Streams contaminated with ochre make up some 5–10% of the total river system. Due to low invertebrate populations in these streams only small populations of eel are present. In the largest river system, Guden å, the lakes are known to act as sinks for ascending elver and yellow eel and the tributaries upstream of the large lakes are devoid of eel.

Lakes

Eel passes are enforced by law where there is any obstruction. There is no record of any lakes without eel populations.

Data on stock and sustained or increased yield

In the Limfjord, a bottom trawl survey during 1980–1990 showed a decrease from 14 eel per unit effort (30 minute trawl) in 1980 to only 1 eel per unit effort during 1986–1990 (Anonymous, 1992). The Limfjord is the largest fjord (1,500 km^2) in Denmark and eel fishing, traditionally very important, has now decreased to very low catches. At the beginning of the 20th century, catches were on average 800–900 t annually and reached 1,300 t in 1915. In the mid-1950s catches started to decline and in 1994 the catch was reduced to only 10 t. Reduction in catch has been common in other fjords, e.g. in Ringkøbing Fjord catches are said to have been reduced by 90% between the 1960s and the 1990s. The official catch for the whole country has fallen by two-thirds between the 1960s and the 1990s.

Yield and production Some estimates of yield in freshwater reservoirs are available from Han Herreds Vejler, by the Limfjord, during the late 1960s. Yield was estimated to be between 1.2 and 8,8 kg ha^{-1} varying with site and fishing efficiency (Anonymous, 1970). Estimates of annual biological production (*P*) and yield (*Y*) are also available from studies in freshwater streams and from the official catch statistics in fjords between 1982 and 1994.

Historical records of stocking

Stocking of lakes has been practised throughout the 20th century by lifting elver and glass eel trapped at sluices and weirs into lakes. This practice had ceased by the end of the 1980s due to a low supply of naturally recruited elver and to avoid the spread of the swimbladder nematode *Anguillicola crassus.*

Since 1987, a national stocking programme funded by the government has been in progress. In the first years, mainly freshwater sites were stocked but, from 1990, the programme was extended to coastal waters. The stocking material is imported glass eel mainly from France and England and raised in heated water to a size of 2–5 g when they are released. The quantities stocked have been between 1.0 and 8.5 million elver annually since 1987.

	kg/ha		Life stage	Data	Reference
Freshwater					
Køge-Lellinge å	93		yellow	production	Rasmussen and Therkildsen, 1979
Brede å	19.6 ±33%		silver	yield	Nielsen, 1982
Bjørnsholm å	9		yellow	production	Bisgaard and Pedersen, 1990
Bjørnsholm å	19-38.6		silver	production	Bisgaard and Pedersen, 1990
Fjords	**1982**	**1994**			
Ringkøbing Fjord	3.2	0.8	yellow & silver	yield	Official catch statistics
Limfjorden	2	0.06	yellow & silver	yield	Official catch statistics
Isefjorden	11.5	2.6	yellow & silver	yield	Official catch statistics

Data on population dynamics

Growth, mortality and production have been studied in streams by fyke netting or electro fishing. Growth from streams has been studied by length at age data and from tagging experiments.

Von Bertalanffy's growth parameters calculated on yellow eel populations in three streams are:

Site	L_∞	k	t_0	Method	Reference
Køge-Lellinge å	59.83	0.119	0.568	Length at age	Rasmussen and Therkildsen, 1979
Giber å	90.3	-1.44	0.053	Back calculated	Bisgaard and Pedersen 1991
Bjørnsholm å	60.1	0.07	-1.63	Length at age	Bisgaard and Pedersen 1990

Annual length increments from individual tagged eel in Giber å were found to be 3.0–5.0 cm for length groups from 10 to 35 cm and 1.0–2.0 cm for length groups from 35 to 60 cm (Bisgaard and Pedersen, 1991).

Mortality rates estimated in the same streams showed decreasing mortality with size and age. The figures are probably biased due to emigration of silver eel from the study sites.

Site	Length cm	Mortality Z	Method
Køge-Lellinge å	11-55	0.65-0.36	Reduction in age groups
Giber å	15-60	1.79-0.26	Reduction in size groups
Bjørnsholm å	15-50	0.91-0.23	Reduction in age groups

The density of eel in streams increases during spring and summer and decreases during autumn and winter. The mobility of the eel stock in streams is probably a result of feeding migration into the stream following a counter-movement to hibernate in the lower parts during winter. The mean number of eel in streams varies with the strength of recruitment to the stream.

Site	Number per m^2	Years	Reference
Køge Lellinge å	1.01	1971-74	Rasmussen and Therkildsen 1979
Vester Vedsted Bæk	13.00	1979-81	Rasmussen 1983
Bjørnsholm å	0.21	1988	Bisgaard and Pedersen, 1990

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

At Vidå sluice on the west coast of Jutland glass eel have been fished commercially and records are available from 1968 to 1990. The highest catches since 1968 were 0.9 t in 1975. Due to very low catches, 5–10 kg in 1989 and 1990, the glass eel fishery terminated in 1990.

Escapement of glass eel

Glass eel are able to migrate into all river systems.

Data on survival of glass eel or bootlace eel after stocking.

Glass eel/ elver In order to restock tributaries deficient in eel, a series of stocking experiments was performed by using small eel of varying sizes, 0.3–1.1 g, and different stocking methods, spot versus scatter. The results suggest that spot stocking resulted in density-dependent mortality, which can be reduced by scatter stocking. Daily instantaneous mortality rates, in the first 3 months after stocking were estimated to be from z = 0.0107–0.0233 a survival of 12–38% after 3 months (Berg and Jørgensen, 1994). A survival of 70% after 3 months of elver stocking in ponds (1 ha or less) is found by mark–recapture (Anonymous, 1970).

Bootlace eel Cultured bootlace eel, size 15–30 cm were tagged individually and introduced into River Giber å. One year after tagging survival was estimated to be 16.3% (Bisgaard and Pedersen, 1991).

Data on economics of stocking

No information is available.

Escapement

Unexploited water bodies.

The number of unexploited water bodies is most probably insignificant. In a few water bodies, eel fishing conflicts with nature conservation. However, fishing for migrating eel is continued at their migrating routes outside these areas.

Silver eel escapement from tagging experiments

A mark–recapture experiment in the River Brede å, where a commercial fishery exists, showed that 60% of the tagged silver eel were not recaptured, but the silver eel may be trapped on their migration route in the Wadden Sea (Nielsen, 1982).

Mark–recapture experiments on silver eel in different parts of the Limfjord showed recapture rates between 43 and 88% (Anonymous, 1970).

Information on conservation measures

Capture of glass eel and yellow eel below legal size is not permitted. Fykes in streams are only allowed to cover one-third of the river width. Silver eel traps in rivers or by the outlet of lakes are not allowed to operate between 1 March and 31 May without a special permit, to protect downstream migration of smolt of sea trout and salmon.

References

Anonymous (1970) *Ålekollokvium i Brøns* – Resuméer-, Brøns, Denmark, 1970.

Anonymous (1992) *Statusredegørelse om fiskeriet i Limfjorden 1992*. Fiskeriministeriet, Ringkøbing, Viborg og Nordjyllands amter, Skov og Naturstyrelsen, pp. 284.

Berg S. and Jørgensen J. (1994) Stocking experiments with O+ eel (*Anguilla anguilla* L.) in Danish streams: post stocking movements, densities and mortality: In. I. G Cowx (ed.) *Rehabilitation of Freshwater Fisheries.* Oxford: Fishing News Books.

Bisgaard J. and Pedersen M. I. (1990) *Population dynamics and production of eel (Anguilla anguilla L.) in Bjørnsholm å.* DFH rapport No. 378/1990.

Bisgaard J. and Pedersen M.I. (1991) Mortality and growth of wild and introduced cultured eel (*Anguilla anguilla* (L)) in a Danish stream, with special reference to a new tagging technique. *Dana*, 9, 57–69.

Nielsen G. (1982)- *Brede Å – river system. Silver eel production – 1981.* DFH rapport.

Rasmussen G. (1983) Recent investigations on the population dynamics of eel. *Proceedings 3rd British Freshwater Fish Conference Liverpool, England.*

Rasmussen G. and Therkildsen B. (1979) Food, Growth and Production of *Anguilla anguilla* L. in a Small Danish Stream. *Rapports et Procès verbaux du Conseil internationale pour l'Exploration de Mer* 174, 32–40.

GERMANY

Eka Hahlbeck[1] and Holmer Kuhlmann[2]

[1]Bundesforschungsanstalt für Fischerei, Institut für Ostseefischerei, An der Jagerbäk 2, 18069 Rostock, Germany

[2]BFA-Fischerei, Inst. für Fischereiökologie, Wulfsdorfer Weg 204, 22926 Ahrensburg, Germany

Habitat

Extent of water currently supporting eel stocks

Coastal waters and estuaries An exact figure for the area is difficult to obtain. The estimate for the North Sea is 1,800 km^2 and for the Baltic 900 km^2 , including the area of estuaries. Data are available for the following biotopes: Elbe estuary, Elbe estuary Cuxhaven, Hamburg Harbour, Elbe weir Geesthacht, lagoon Wyk/Föhr, North Sea near Elbe estuary, estuary of river Oste, rock littoral of Helgoland (Penaz and Tesch, 1970; Löwenberg, 1979) .

For the Baltic Sea data are available for the stock in the Oder-estuary connected with the Oder-lagoon (Dietzsch, 1978) and from the open Baltic (Hahlbeck, 1991). In Germany during the best years (1950s/1960s), the total catch from the North Sea and the Baltic was much higher than from inland waters. Eel fishing along the whole region of the German coast, especially in the brackish waters of the Baltic coast is important (yellow and silver eel) (Jarmatz et al., 1986).

Coastal lagoons On the German Baltic coast there is only one coastal lagoon, the legendary Conventer See which many years ago had a maximum yield of 60 kg eel ha^{-1}. In the 1970s land reclamation took place which cut the lagoon off from the Baltic causing a severe decline in eel catches. Natural immigration of eel is no longer observed.

Lakes, rivers, canals According to Meyer–Waarden (1968) the total inland water area of Germany is 4,000 km^2 from which 3,000 km^2 are suitable for eel (75%). The official fisheries census (1993) states that the total area used by commercial fishery is 480 km^2 for rivers and 1,820 km^2 for lakes. This amounts to a total of 2,300 km^2. The area used by recreational fishery is not known.

The eel is the main species for commercial fishery in lakes and rivers.

Areas of water inaccessible to eel due to chemical or physical obstructions

Lakes No details have been published. A rough estimate is that about 5% of all lakes are influenced by physical obstructions; no chemical pollution, as a barrier to eel ascent, is known.

Rivers/canals Most of the southern rivers have several dams. For example, according to Meyer–Waarden (1968) there are 12 dams in the German part of the River Mosel with a catchment of 30,000 km^2.

The eel, with its wide ecological adaptability, will find living conditions and food in the whole German water area, and also in polluted rivers and in reservoirs.

Data on stock and sustained or increased yield

CPUE data are very scarce. For the German Bight Löwenberg (1979) gives data for eel trawling, but only for one year. For the River Elbe CPUE data are available for 20 years. Total catch fluctuates around the long-term average. Since 1980 a sharp decrease in the number of small eel has been observed. Similar results are reported from the River Weser. Berg (1988) gives CPUE data for Lake Constance (5,390 km^2) over a very long series of years from 1950 to 1982. In addition a comparison between different gears is made.

The density of the eel stocks in Europe probably depends on the one spawning stock, so we have reason to believe that stock fluctuations will influence the eel yields in all European countries in a similar way.

Gear	Mesh size mm	Median length cm	± S.D.
Pound net	11	50.1	10.4
Pound net old	24	82.5	8.4
Electro-gear	-	40.5	10.7
Electro-gear + net	-	43.9	9.4
Longline	-	59.2	10.6
Trawl	-	60.0	16.9

Historical records of stocking

Detailed stocking data are available for Lake Constance from the 1940s until 1982. Stocking intensity and total catch generally were positively correlated.

Stocking of glass eel		Resulting yield	
Period	Numbers	Period	kg/ha
1880		1880	0.001
from 1950	69,200	1975-1982	1
from 1960	173,000	1975-1979	3-4
from 1970	707,000	1980-1982	5-6

In Lake Constance yields rose 10 years after stocking. Estimates show that at least 10% of stocked glass eel reached commercial size. For several other rivers stocking data are available until 1968 (Meyer–Waarden), but recent data are very scarce. From the Hebrum station (River Ems) glass-eel catch data are available from 1928 to the present. The last high catch of glass eel was in 1976 (more than 3,000 kg); since 1981 this figure has been under 1,000 kg and from 1983 to 1995 under 200 kg (Schmeidler, 1963; Aalversandstelle des DFV). The total catch is used for stocking.

Eel stocking data are available from 1973 to the present. In the best years, from 1974 to 1980, every year 8 t elver and 70 t fingerling were released (1993 3 t elver and 29 t fingerling).

Data on population dynamics

Detailed investigation on population dynamics have been carried out in Lake Constance (Berg, 1988). For example the growth rate per year was between 4.63 and 5.22 cm. Jarmatz et al. (1986) investigated the eel from coastal Baltic waters. Dietzsch (1978) made population dynamic investigations in eel from the Oder Lagoon (Oder–Haff). Penaz and Tesch (1970) conducted investigations on the sex ratio and growth of eel from the North Sea and River Elbe. Anwand and Valentin (1982) worked on eel from different lakes in the eastern part of Germany.

All data are relatively old. No recent data are available for the big Rivers Rhine, Weser, Elbe, Eider and Oder, nor for the big lakes or marine areas.

The following table summarises the data from Penaz and Tesch (1970).

Age groups	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Length (cm)	9.4	15.5	23.2	26.4	30.0	33.7	38.6	43.9	52.8	54.8	64.0	70.7	72.1

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

The only recruitment data available concerning glass eel are the data from Hebrum. Additional data on bootlace catches are collected in the *Aalversandstelle* of the German Fisheries Association. Glass eel as well as bootlace are all used for stocking purposes.

Escapement

Even the largest gears (i.e. otter board stow nets) do not block the total diameter of a river. According to information from the River Elbe (Köthke, pers. comm.) the largest stow net has a diameter of 40 x 3 m, whereas the total width of the river is 300 m. The stow net does not reach the bottom. Trials have led to an estimate, that, using 7 stownets of the diameter mentioned, about 5% of the migrating eel are caught. The catch, for example, of the stow net No. 4 was influenced only very weakly whether or not stow nets 1–3 were in action. The situation is similar in all big rivers with stow-net fishery.

References

Anwand K. and Valentin M. (1982) Age and growth of eel in natural inland waters. *Sportfischer Informationsdienst* pp. 23–26

Berg R. 1988: *Der aal im Bodensee* Verlag Josef Margraf, Gaimersheim.

Dietzsch D. (1978) Fishery biological studies on eel stocks in the Oder Lagoon. *Wissenschaftliche Zeitschrift der WPU Rostock* 4, 447–453.

Hahlbeck E. (1991) Eel fisheries and eel catches in the coastal zone of Mecklenburg-Vorpommern and present distribution of the swim bladder parasite Anguillicola). *Arbeiten der Deutsche Fischerei Verb.* 53, 25–39.

Jarmatz K., Winkler H. and Biester E. (1986) Fishery biological studies concerning eel stocks in the DDR coastal waters in 1982. *Wissenschaftliche Zeitschrift der WPU Rostock* 3, 48–53.

Koops H. (1988) Study on protection and conservation of the eel stocks especially on the glass eel stocks. *Der Fischwirt*, Vols. 6+7.

Löwenberg U. (1979) *Investigation in the eel of the German Bight, biology and fishery*. Diplomarbeit Fachbereich Biologie, Univ. Hamburg.

Meyer–Waarden P.F. (ed.) (1968) *The Eel Fishery in Germany*. Verlag Heenemann kg, Berlin

Müller H. (1975) *The Eel*. A. Ziemsen-Verlag, Neue Brehm-Bücherei; Nr. 471

Penaz M. and Tesch F.-W. (1970) Sex rate and growth of the eel (*A. anguilla*) in different biotopes of the North Sea and the River Elbe. *Berichte der Deutschen Wissenschaftlichen Kommission fuer Meeresforschung* 21, 290–310.

Rahn J. (1955a) Investigation in age and growth of the eel stock in the Sacrow Lake. See. *Zeitschrift fuer Fischerei*, 4, 235–256.

Schmeidler E. (1963) Observations on the development of the quantity and the time dependence of glass eel ascent in the River Ems (Hebrum) in the years 1950–62. *Dt. Gewässerkundl. Mitt.* 7, 84-86.

Tesch F.-W. (1983) *The Eel*. Parey-Verlag ,Hamburg.

Thurow F. (1957) *Contributions to the Biology of the Eel (*A. vulgaris*)*. Phil. Diss. Kiel.

Thurow F. (1959) Yield and growth of the eel in the western Baltic. *Zeitschrift fuer Fischerei* 13 N. F. Heft 7/8.

IRELAND (NORTHERN IRELAND)

Robert Rosell
Department of Agriculture for Northern Ireland, Aquatic Systems Group, Newforge Lane, Belfast BT9 5PX, N. Ireland

Habitat

Extent of water currently supporting eel stocks

Estuaries The Bann and Foyle estuaries, totalling 21 km^2 in combined area, are the only significant estuaries in NI. Both contain occasionally lightly fished populations of yellow eel in addition to seasonally migrating elver and silver eel. Areas, intertidal area and substrate types are listed in Buck (1996). Water quality parameters are described by Service (1993).

Coastal lagoons There are no coastal lagoons containing significant *Anguilla anguilla* stocks.

Lakes The extent of eel habitat in Northern Ireland can be estimated on the basis that while there are no fish survey data for most lakes, it is known that eel exist in all but a very few small upland sites. The total lake area is circa 626 km^2 (Smith et al., 1991). It is probable that eel exist in 95% or more of the recorded total lake area, i.e. approximately 600 km^2 of eel habitat.

Coastal waters Most NI coastal waters are of high salinity and essentially marine in character. There are no significant *A. anguilla* stocks. In a study of fish entrainment on power station intake screens (Moorehead and Service, 1992) eel have been found in low numbers at three of four sites, all in estuaries or where there is freshwater influence.

Rivers/canals There is no estimate available of total river area in NI, but in eel habitat or production terms this is not significant in relation to lake area. Some information can be extrapolated from official water statistics (Anonymous, 1979a), which contain some useful data in relatively raw form on hydrometric areas, and river basin areas. There is of the order of 20 km^2 of river surface area, most of which will contain eel at relatively low density (as compared with the figure of approximately 600 km^2 of lakes containing eel – see above). The rivers feeding Lough Neagh, by far the largest catchment in Northern Ireland, are exploited as part of the emigrating silver eel fishery from the lake.

Areas of water inaccessible to eel due to chemical or physical obstructions.

Lakes There are no specific data. However, inaccessible areas can be assumed to be an insignificant proportion of total water surface area likely to be useful for eel production.

Rivers/canals The *Water Quality Map for Northern Ireland* (Anonymous, 1995a) shows that at least Cyprinid water quality conditions (as listed in the EC Freshwater Fish Directive) are met in all NI rivers. There are hence no chemical barriers to eel migration. Physically inaccessible reaches are very limited and only in upland or steep coastal rivers, not significant in terms of total area.

Data on stock and sustained or increased yield

Data on annual declared catches for all commercial licences since 1966 are held by the Fisheries Division of the Department of Agriculture for Northern Ireland. Catch data are dominated by the output of the Lough Neagh Fishery, which is more than 20 times that of the Erne, the only other major fishery. Other small fisheries are insignificant in the total. Mean annual total NI declared catch of all eel since 1986 is 730 t, range 650 t to 830 t. Over the past 30 years the Lough Neagh data show a slightly declining trend in total catch and, within that, a shift from silver to yellow eel harvest as the bulk of the total output (Anonymous, 1995b).

Parsons et al. (1977) analysed sex ratios of silver eel for Lough Neagh, in relation to elver stocking periods, and showed an increase in numbers of smaller male silver eel in catches following periods of upstream elver transport.

Kennedy and Vickers (1993) gave a general description of the Lough Neagh fishery and changes in practice, eel harvests 1960 to 1988 and silver eel runs in relation to river discharge. Following on from Parsons et al. (1977), Kennedy and Vickers also made a further analysis of the sex ratio in silver eel, showing that the effect of elver transport in increasing proportions of males had been temporary, indicating possible genotypic determination of sex of the eel.

Historical records of stocking

Parsons et al. (1977) provided data on quantities of glass eel transferred to Lough Neagh from the estuary of its outflowing River Bann. Anonymous. (1995b) brings the time series up to 1995. Quantities were relatively large between 1965 and 1978 (mean 6.1 t) and small (mean 2.1 t) from 1979 to 1995. Between 1994 and 1995, glass eel from the River Severn in England were stocked in eight seasons, the quantities ranging from 9 t to 2 t. Moriarty and Tesch (1997) give details of quantities of glass eel transferred from the estuary of the River Erne to the lakes upstream since 1965, ranging from 0.4 to 4.5 t, mean 1.3 t.

Data on population dynamics

Lough Neagh silver and yellow eel data were recorded by DANI at various times from 1965 to 1978, and some of the trends in these data have been summarised by Kennedy and Vickers (1993). Mean lengths and ages of eel in both yellow and silver eel catches declined in the 1960 and 1970s. Male and female silver eel averaged 37.5 cm and 53.9 cm long, respectively, in 1973 (Anonymous. 1972). In Lough Neagh, growth rates for males and females are similar, at 2–3 cm per year, with males migrating after 10–13 years in freshwater and females after 17 years (Anonymous., 1969a). Other populations have been shown to have faster growth rates (Moriarty, 1973, Anonymous., 1976).

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

Fishing takes place only on the River Bann, for transport to Lough Neagh. Ladder traps are operated at a weir at the head of the tide and it is believed that a large proportion of the ascending glass eel enter these. Data on numbers (Anonymous, 1995b) are summarised under historical records of stocking above.

Escapement of glass eel

There is no coastal fishing for glass eel. Populations are free to develop in all river systems in NI. Experimental glass eel fishing was attempted in the Bann estuary in 1996 and made a considerable contribution (in excess of 30%) to the number of elver transported to Lough Neagh. It is not known to what extent these elver would have reached the ladder traps if left to migrate naturally.

Data on survival of glass eel after stocking

Male Lough Neagh eel migrate to sea at ages 10–13 years and females at 17+ years (Anonymous, 1969a). Growth rates are of the order of 2 to 3 cm per year, meaning that eel of both sexes reach market size as yellow eel (30 to 40 cm) in about 10 years. An analysis of existing elver run data and catches, (Anonymous 1995a), using a 10 year lag to yellow eel and an average 15 year lag to silver eel, demonstrates a yield per recruit of 105 g of eel per elver transported, or 314 kg of eel per kg of elver (3,000 elver = 1 kg) over the harvest years corresponding to elver supply over a 20 year period from 1965. Production per unit area averages approximately 17 kg ha^{-1} over the same period.

Similar estimates of yield can be made for Lough Erne. Elver and eel harvest data are presented in Moriarty and Tesch (1997). Harvest data are supplied annually to DANI (unpublished) and growth rates have been measured by Moriarty (1973). The latter suggests that most eel should reach market or migration sizes (> 45 cm) in around 8–9 years. Applying a 10 year lag to the elver to adult production data, the Erne system is currently yielding 19 g of eel per elver transported, or 56 kg eel per kg elver transported. Production per unit area averages approximately 5 kg ha^{-1} over the same period. These figures are almost certainly underestimates due to difficulties in collating data on the total catch, and should probably be at least doubled, resulting in an output of the order of 40 g of eel per elver, as opposed to 105 g from Lough Neagh (above). It is unlikely that the Erne elver run is much underestimated due to the probability of the power station at the trapping point on the river preventing other natural upstream migration.

Data on economics of stocking

Although elver stocking to Lough Neagh has been carried out over two defined periods with known numbers of elver, a full analysis of the economics or effectiveness of this practice has never been carried out. Following initiation of elver transport Parsons et al. (1977) found a significant correlation between numbers of elver stocked in 1936–1947 and yellow eel catch 8 years later, corresponding to the approximate known lag after which growth should allow recruitment to the yellow eel fishery. Further analysis has not produced statistically significant correlations since. Analysis of more recent data over a longer time series (elver years 1960–1988, Anonymous, 1995b) yields a weak positive but not statistically significant correlation. A lack of information on catch per unit effort or any other measure of stock density in the yellow eel fishery prevents more detailed analysis. There are no data on costs of the transport and stocking operation.

Escapement

Escapement of glass eel

No information.

Escapement of silver eel

There are no summary references or reliable estimates of silver eel escapement available. This could potentially be measured in the Bann system by using the sequential downstream trapping facilities at Toome, Portna and Movanagher.

Figures for the Toomebridge weir at the outlet of Lough Neagh and the Kilrea weir 23 km downstream are given in Anonymous (1992). The mean annual catches over the period 1962–1992 were 127 t and 80 t, respectively. A lake, Lough Beg, of 700 ha lying downstream of Toome together with 19 km of river contributes to the catch at Kilrea. It is assumed, however, that the greater part of the Kilrea catch, 39% of the total for the catchment (and up to almost 50% in some years) derives from escapement from the 10% free gap at Toome.

A preliminary analysis shows that a high proportion of the water area of Northern Ireland is exploited or partially exploited for both yellow and silver eel – thus all the lakes and rivers feeding Lough Neagh and Lough Erne can be considered as at least partially exploited by yellow and silver eel fisheries, and the Foyle system, while extensive, has not in recent years yielded commercially viable quantities of eel (although fishing methods were probably inefficient). These three catchments account for circa 90% of the land and inland water area of Northern Ireland. The only totally unexploited waters contributing to a spawning escapement are some small lakes and rivers in minor coastal catchments without extensive lake systems.

Some escapement is protected by a legislative requirement for silver eel fisheries to maintain a free gap equivalent to 10% river width at all times (Anonymous, 1979b). It is probable that escapement exceeds this 10% where applied (Bann, Erne and Quoile systems).

It is only possible to guess on a very approximate basis at the proportion of silver eel reaching the sea. The output of silver eel is dominated by the Bann and Erne systems, with some additional eel from other systems. The Erne system has been estimated to be somewhat underexploited, but does have a power station on its exit which may damage some silver eel. Escapement from the Bann system almost certainly exceeds the 10% which the legal free gap would allow if eel migrated proportionally to river width and fishing were 100% efficient. Escapement from the Erne system may be as high as 50% if current estimates of catch and potential production are correct. As a province-wide figure, a total potential spawning escapement of perhaps 30% of a current silver eel run averaging approximately 300 t would be a reasonable starting point, i.e. approximately 100 t of silver eel.

Number and extent of unexploited water bodies

In Northern Ireland, the extent of unexploited water is very limited (see escapement of silver eel, above), and is probably less than 20 km^2 in total eel habitat of around 650 km^2. Angler exploitation in considered insignificant.

Information on conservation measures

Close seasons for eel fishing run from March to May, inclusive, in the case of silver eel weirs, and 8 January to 30 April for fyke net fishing. These in effect only reflect the practical seasonality of eel fishing. Eel netting is banned within 1.6 km of river mouths and in certain defined areas of Lough Erne. Longlining is only permitted in Loughs Neagh and Erne. In Lough Erne, effort is restricted by limitations on boat size. Glass eel may only be fished under special conditions for restocking purposes. There is a legal size limit of 30 cm for yellow eel, though for marketing purposes the Lough Neagh co-operative prefers eel longer than 41 cm. Silver eel weirs must preserve a 10% river width free gap at all times (Anonymous, 1969b, 1979b).

References

Anonymous (1969a) *Annual report on research and technical work – Fisheries Research Laboratory. Department of Agriculture for Northern Ireland*, HMSO, Belfast, pp. 76–77.

Anonymous (1969b) *Fisheries Act (Northern Ireland) 1966*, reprint to 1969. HMSO, Belfast.

Anonymous (1972) *Annual report on research and technical work – Fisheries Research Laboratory. Department of Agriculture for Northern Ireland*, HMSO, Belfast, pp. 99–100.

Anonymous (1976) *Annual report on research and technical work – Fisheries Research Laboratory. Department of Agriculture for Northern Ireland*, HMSO, Belfast, pp. 115–117.

Anonymous (1979a) *Northern Ireland Water Statistics. Water service, Dept. of the Environment for Northern Ireland. Belfast*. HMSO.

Anonymous (1979b) Eel fishing regulations (Northern Ireland) 1979. *Statutory rules of Northern Ireland*, No. 19. HMSO, Belfast.

Anonymous (1992) Lough Neagh Fishermen's Co-Operative Society Ltd. *Annual report*.

Anonymous (1995a) *Water quality map for Northern Ireland*, DOE(NI) Calvert House, Castle place, Belfast.

Anonymous (1995b) Lough Neagh Fishermen's Co-Operative Society Ltd. *Annual report*.

Buck A.L. (1996) *An Inventory of UK estuaries*. Joint Nature Conservation Committee 1996. Nos. 156 (Lough Foyle), 157 (Bann Estuary). HMSO. London, (in press).

Kennedy G.J.A. and Vickers K.U. (1993) Salmon and eel. (eds Wood R.B. and Smith R.V.) *Lough Neagh – the ecology of a multipurpose water resource*, Kluwer Academic Publishers, Dordrecht, pp. 397–417.

Moorehead P. and Service M. (1992) Capture of fish on screens of power stations in Northern Ireland. *Irish Naturalists Journal* 24, 3-8.

Moriarty C. (1973) Studies of the eel *Anguilla anguilla* in Ireland. 2. In Lough Conn, Lough Gill, and North Cavan Lakes. *Irish Fisheries Investigations* Series A, 13 13 pp.

Moriarty C. and Tesch F.W. (1997) Possible increase in catch of Atlantic elver *Anguilla anguilla* in 1993 and 1994. *Ecology of Freshwater Fish* 5, 213-215.

Parsons J., Vickers K.U. and Warden Y. (1977) Relationship between elver recruitment and changes on the sex ratio of silver eel *Anguilla anguilla* L. migrating from Lough Neagh, Northern Ireland. *Journal of Fish Biology* 10, 211–229.

Service M. (1993) *Review of Monitoring in Northern Ireland's Coastal waters and proposals for an integrated Classification programme*. Department of Economic Development, Report TI 89/3146.

Smith S.J., Wolfe-Murphy S.A., Enlander I. and Gibson C.E. (1991) *The Lakes of Northern Ireland: An annotated inventory*. Countryside and Wildlife Research Series, No 3. HMSO, Belfast.

IRELAND (REPUBLIC)

Christopher Moriarty[1] and Julian Reynolds[2]
[1]Marine Institute, Fisheries Research Centre, Dublin 15, Ireland
[2]Department of Zoology, Trinity College, Dublin 2, Ireland

Habitat

Extent of water currently supporting eel stocks

Estuaries No details of extent have been published and, on account of the difficulty of determining the seaward boundary of a number of estuaries, an exact figure is difficult to obtain. Populations of eel are known or assumed to exist in the estuaries of 237 rivers. Of these, 16 estuaries are greater than 1 km^2 in extent and professional fishing for yellow eel takes place in two of these. Trapping of elver for transportation takes place at the tidal boundary of five estuaries. Experimental glass eel fisheries occur in three.

Coastal lagoons Only six substantial coastal lagoons exist in Ireland, of which one has an area of 3 km^2 and the others are less than 1 km^2. Two are man-made. Eel populations exist in all but only one yields a professional catch.

Coastal water Experimental eel fishing in coastal waters around Ireland has yielded negative results and it is believed that there is no significant population of marine-dwelling eel.

Lakes Freshwater lakes total 1,445 km^2. Eel fishing takes place in 745 km^2 of this area, approximately 50% of the total habitat.

Rivers/canals Rivers described as *main channel* number 237 with a total length of 5,341 km. At least 95% of these are accessible to eel, either because of the absence of any obstructions or because fish passes or capture and transportation allow elver to enter them. Eel fishing takes place on ten of these, but depends largely on silver eel migrating from upstream lake systems. The sole exception, an exploited river system with no lakes, is the Barrow, length 190 km.

Areas of water inaccessible to eel due to chemical or physical obstructions

Lakes

Eel are present throughout the 144,500 ha of lakes except for one man-made lake of 12 km^2 and an insignificant area of small mountain lakes and lakes which drain by percolation.

Rivers/canals

It is estimated that not more than 5% of the 5,341 km of main channel rivers are inaccessible to eel. They are absent from the tributaries of the man-made lake mentioned above and from an unspecified number of mountain torrents. Eel are extremely scarce in the Avoca catchment, 106 km main channel, to which access is prevented by mine effluent close to its mouth.

Data on stock and sustained or increased yield

Data on catch per unit effort by a standard train of ten small (<50 cm mouth diameter) fyke net pairs in 38 water bodies are given in Moriarty (1988) together with mean length of specimens and growth rate calculated as a linear regression on length at age of capture. The number of eel caught per unit ranged from zero (in coastal water) to 466. The latter was exceptional and based on only one unit. A narrower range, from 3 to 205 was observed elsewhere in fresh water. This standardised catch per unit is used in Ireland to compare population density and structure between water bodies. In the preparation of management plans it has been adopted by reference to known commercial fishing yield and effort in Lough Neagh to estimate potential catch in other fisheries.

Construction of a hydrodam at the tidal boundary of the River Shannon in 1928 significantly reduced the numbers of elver ascending to fresh water in the Shannon lake system which has a total surface area of 340 km^2. A management plan based on capture and transportation of elver, elimination of commercial capture of yellow eel and concentration of silver eel capture to three fishing stations was initiated in 1958. Fyke net sampling of yellow eel began in 1969 and has continued up to the present. These surveys showed that the greater part of the eel population inhabited Lough Derg, the lowermost of the lakes in the system. Lakes upstream were populated by relatively smaller numbers of eel of greater size and age than in Lough Derg. The implication was that migration of the eel to the upstream lakes takes place so slowly that a large proportion of the population reaches maturity while still in Lough Derg and therefore the upstream lakes are under-populated.

A substantial increase in silver eel catch began to be observed in 1979 and the numbers of eel per unit effort in experimental fyke nets increased by 62% between 1969 and 1981, following which the sampling results suggested that a steady state of population had been attained. The mean annual silver eel catch at Killaloe, the principal fishery, from 1979 to 1988 was 27 t, as against 18 t for the previous decade. Comparison of the Shannon lakes with Lough Neagh (Northern Ireland) showed that fyke net CPUE for the Shannon lakes was nearly double that of Lough Neagh while growth rates and length frequencies were similar in both. However, the yield per hectare in Lough Neagh was 22 kg as against less than 2 kg on the Shannon lakes (Moriarty, 1987).

The hypothesis that the low yield of the Shannon lakes resulted from under-fishing began to be tested in 1992 by the development of an experimental commercial yellow eel fishery. In 1994, 36 two-man crews operated 50 fyke nets per crew and the number of silver eel trapping stations was increased. The catches for 1994 were 55 t of yellow eel and 38 t of silver (McCarthy et al., 1994a).

The current yield of 2.7 kg ha^{-1} from a mean stocking rate of 357 elver ha^{-1} appears to be extremely poor. Sampling of the fyke net catches continued to show a high population density. A study of silver eel migration, including extensive tagging and releasing of silver eel, indicated a very high rate of escapement. The nets of the fishery at Killaloe, through which all eel from the 340 km^2 of lake migrate, extend over 90% of the width of the river and under normal flow conditions extend from surface to bed. In spite of this, only 20% of 1,170 silver eel tagged and released upstream of the nets were recaptured (data extrapolated from McCarthy et al., 1994b).

In the oligotrophic Burrishoole system yellow eel are unexploited but all migrating silver eel are trapped. The number of silver eel trapped since 1959 has gradually declined; however, the total yield has not decreased as there has been a change in sex ratio from 94.5% male in 1962 to 37.5% in 1988. The mean length of males has also increased by 16.5% and females by 27.6%, coupled with an increase in age at migration for both sexes (Poole et al., 1990).

Historical records of stocking

As outlined above, stocking by overland transfer of elver intercepted in their migration from tidal to fresh water, has been in progress since 1958 in the River Shannon. Elver, from two adjacent rivers, the Maigue and the Feale have been captured and transferred to the Shannon lakes from time to time but the principal source is the main stream of the Shannon. The great majority of these elver are age 0^+. This stocking has been supplemented by transfer of bootlace eel, the majority aged between 2^+ and 10^+, captured at a fish pass 18 km upstream of the tidal boundary. (Reynolds et al., 1994; Walsh, 1994).

Data on population dynamics

Values for L_∞ were calculated for yellow eel captured by fyke net stocks in the River Barrow and in Lough Derg on the River Shannon:

Site	Method	L_∞	k	to	Reference
R. Barrow	Back calculation	105	0.05		Moriarty (1983)
Lough Derg	Back calculation	87	0.02	-2.5	Walsh et al (1993)
Lough Derg	Age at capture	79	0.04	-1.4	McCarthy et al (1994a)
Lough Derg	Back calculation	103	0.02	-4.1	Poole and Reynolds (1996b)

However, it seems likely that the sizes and ages attained by silver eel are of far greater significance in the context of eel management and these are usually well below the L_∞ value:

	Galway		Killaloe		Burrishoole	
	males	females	males	females	males	females
Mean length (cm)	36	47	38	60	37.3	50.4
Length range	30-42	38-87	30-43	43-90	29-46	41-97
Age range	7-17	12-19	7-16	9-21	10-33	8-57
Reference	Moriarty (1991)		Moriarty (1989)		Poole & Reynolds (1996a)	

Random measurements of silver eel at Killaloe on the River Shannon between 1972 and 1988 showed a significant reduction in length of females at migration, in the order of 10 cm total length, from means of 60 cm to 50 cm (Moriarty, 1989). On the other hand systematic measurements of silver eel on the Burrishoole River between 1959 and 1988 showed an increase from 35 to 45 cm (Poole et al., 1990).

Silver eel of the River Shannon showed a very distinct difference in lengths attained by males and females: eel of 45 cm length were extremely rare and those examined were female. Smaller specimens were all male and the larger ones were all female. In the neighbouring catchment of the River Corrib both male and female silver eel were considerably smaller and overlapped in length, females of as little as 39 cm being observed (Moriarty,1989). In the Burrishoole, the overlap between shortest female and longest male was 5.5 cm in 1988.

Annual survivorship was calculated for the Shannon lakes Derg and Ree based on an assumption of constant recruitment and fishing mortality. Values ranged from 68% to 74%, derived from instantaneous mortality z = 0.30–0.38 (McCarthy et al., 1994b).

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

In Ireland all glass eel captured are used for on-growing, usually within the river system of capture. Less than 50 kg of glass eel are used in eel culture. All glass eel for these purposes are captured in ladder traps at the tidal boundary and the catches include a small proportion of older eel. However, the variations in annual catch reflect the extent of migration of newly arrived eel into fresh water. Capture takes place annually on two major rivers, Shannon and Erne and to a much smaller degree in four others.

Catches on the Shannon have been recorded since 1977. High returns, from 2 to 7 t, were observed between 1979 and 1982. In the subsequent years, annual catch has never been greater than 1.6 t.

Catch data for the River Erne have been recorded since 1962. They were not especially large in the 1970s and did not show any marked decline thereafter. Highest catches of 4 t were made in 1982 and 1994 (Moriarty and Tesch, 1997).

Escapement of glass eel

Glass eel populations are free to develop in the absence of exploitation in 231 of the 237 Irish rivers.

Data on survival of glass eel or bootlace eel after stocking

McCarthy et al. (1994b) concluded that between 50 and 100 t of silver eel per annum escape from the Shannon lake system. The known fishing mortality in 1994 was 93 t. This suggests a possible production (catch plus spawning escapement) of 193 t or 4.2 kg ha^{-1} from stocking at a rate of 357 glass eel ha^{-1}.

Data on economics of stocking

The natural recruitment to the Shannon lakes is known to be substantial because few silver eel are older than 21 years and good catches of eel continued to be made for 30 years after elver migration was impeded by the building of a hydrodam at the tidal boundary. Fyke net sampling between 1969 and 1982 indicated a doubling of the exploitable yellow eel population as a result of initiating elver transport in 1959 (Moriarty, 1987). The costs of the transfer operation have not been quantified, nor were the increased stocks exploited efficiently. Therefore the economic return cannot be calculated.

Escapement

Number and extent of unexploited water bodies

Rivers unexploited for eel in Ireland number 227 from the total of 237. It is estimated that the eel of one third of the length of these rivers are exploited, totalling 1,800 km. Of the lakes, 800 km^2 are exploited and 645 km^2 are free. McCarthy et al. (1994b) estimated that escapement of silver eel from the Shannon system is at least equal to the annual catch of yellow plus silver eel. On the Burrishoole, virtually all descending silver eel are caught and sold but this is unique in having a highly efficient salmon smolt trap which prevents the escape of silver eel. The Shannon is probably the most efficiently exploited commercial eel fishery in the State and therefore escapement from all other fisheries may be assumed to be greater than the total catch.

Information on conservation measures

Capture of glass eel is forbidden by law except when authorised for stock-enhancement purposes. A free gap of at least 10% of the width of the river must be included in all fisheries for silver eel. Commercial capture and sale of eel may be carried out only by licensed fishermen or dealers. Persons found in possession of eel by law enforcement officers must be able to provide evidence that the eel were legally caught or purchased.

References

McCarthy T.K, Allison J., Callaghan R., Purcell P. and Copley L. (1994a) *Yellow eel stocks in the River Shannon and the development of a fyke net fishery.* Report to Electricity Supply Board.

McCarthy T.K., Cullen P., Faherty K. and O'Farrell M. (1994b) *River Shannon silver eel: Population biology, factors influencing downstream migration and commercial fishing.* Report to Electricity Supply Board.

Moriarty C. (1983) Age determination and growth rate of eel, *Anguilla anguilla* (L). *Journal of Fish Biology* 23, 257–264.

Moriarty C. (1987) The eel stocks of the Shannon system and prospects for the development of the fishery. *Fishery Leaflet (Dublin).* 139.

Moriarty C. (1988) The eel in Ireland. *Royal Dublin Society Occasional Papers in Irish Science and Technology* 4.

Moriarty C. (1989) The silver eel catch on the lower River Shannon, Ireland. *EIFAC Working Party on Eel, Porto, 1989.* pp 12.

Moriarty C. (1991) Management of the Corrib eel fishery. *EIFAC Working Party on Eel, Dublin, 1991*, pp 12.

Moriarty C. and Tesch F.-W. (1997) Possible increase in catch of Atlantic elver *Anguilla anguilla* in 1993 and 1994. *Ecology of Freshwater Fish* 5, 213-215

Poole W R and Reynolds J.D. (1996a) Growth rate and age at migration of *Anguilla anguilla. Journal of Fish Biology* 48, 633–642.

Poole W R and Reynolds J.D. (1996b) Age and growth of yellow eel *Anguilla anguilla* (L.) determined by two different methods. *Ecology of Freshwater Fish* 5, 86–95.

Poole W.R., Reynolds J.D. and Moriarty C. (1990) Observations on the silver eel migrations of the Burrishoole River System, Ireland, 1959 to 1988. *International Revue der Gesamten Hydrobiologie* 75, 807–815.

Reynolds J.D., Donnelly R., Molloy S. and Walsh, T. (1994) *Glass eel, elver and juvenile eel programme.* Report to Electricity Supply Board.

Walsh T. (1994) *Biological studies of glass eel* Anguilla anguilla *(L.) in the Shannon Estuary, Ireland.*MSc thesis, Trinity College, Dublin.

Walsh T., Moriarty C. and Reynolds J. (1993) Using OPRS electronic scanning in age determination of the eel *Anguilla anguilla* (L.). *EIFAC Working Party on Eel, Olsztyn, Poland, 1993.* pp 7.

GREAT BRITAIN

Brian Knights
Applied Ecology Research Group, University of Westminster, 115 New Cavendish Street, London W1M 8JS, UK

Habitat

Extent of water currently supporting eel stocks

Estuaries Estuaries form a substantial part of the coastal zone of Britain, with 155 larger estuaries comprising an intertidal/channel area of *ca.* 5,300 km^2. Fyke nets, traps and pair trawls have been or are currently being used to exploit eel stocks in shallower, warmer, productive waters with depositing shores in the south and east, such as the Humber, Wash, Solent, Severn and Dee (Morrice, unpublished data). The Thames is the only well-defined estuarine fishery for which information is available (Naismith and Knights, 1993). However, the area able to support reasonable eel stocks is probably 40–50% of the total, i.e. *ca.* 2,500 km^2.

Coastal lagoons There are no significant coastal lagoons in Great Britain.

Coastal waters Eel stocks are high enough to support occasional trawling in shallower coastal waters in the southern North Sea and English Channel. Eel also appear in by-catches in other near-coastal waters (unpublished data from Morrice, McKinnon and Potter; G. Williams, pers. comm.). Taken together with the estuaries above, a conservative estimate of the total area of saline waters occupied by eel would be 5,000 km^2.

Lakes Lakes in Great Britain number:

Area (km^2)	Number
< 1	1,665
1–10	50
10–100	2

The total area of lakes which could support eel stocks is *ca.* 1,924 km^2 (Dill, 1993).

Rivers/canals The total area of inland water is 2,404 km^2, of which still waters account for about 80%, thus the area of rivers and canals which could support eel is about 500 km^2. Estimates of length of river vary from 38,820 to 58,380 km for 155–160 *main* rivers, 1,445 rivers in total (Dill, 1993).

Areas inaccessible to eel due to chemical or physical obstructions

All inland waters, even acid ones, should be capable of supporting eel if access is possible (Turnpenny, 1989; Mann, 1995). Relatively few are totally inaccessible.

Lakes Man-made lakes number approximately 500. Access to some of these, and to some natural lakes, is restricted because of isolation from rivers or by water storage and river regulation purposes. The area totally inaccessible is, however, believed to be relatively small.

Rivers/canals There are few totally unpassable obstructions of any significance, mainly because of the lack of major hydro dams in comparison with other European countries. Large tidal barriers built in recent years have had to be fitted with fish passes. However, most main rivers are carefully regulated for flood control, water supply and navigation, with numerous weirs and sluices (plus some tidal-flap or gate barriers to the sea in low-lying areas such as East Anglia and the Somerset Levels). The number and relative severity of such obstructions have been shown to inhibit elver and yellow eel immigration and hence full utilisation of catchments. Data have been published for the Thames (Naismith and Knights, 1988, 1993), Severn (Aprahamian, 1988; White and Knights, 1994, 1997a, 1997b) and some smaller rivers (Turnpenny, 1989; Mann, 1995).

This work has shown that upriver sites may not be utilised or stocks may achieve lower densities and productivities than might be expected. For example, in surveys of the Severn, 93% of sites on tributaries feeding the estuary but only 69% of those above the tidal limit contained eel (Aprahamian, 1988). Comparable figures for the Thames are 62% and 34%, respectively (Naismith and Knights, 1993). Of 181 streams studied by Turnpenny (1989), 65% with pH >6.1 contained eel. Thus 60% could be used as an approximation of the area of riverine waters actually inhabited by eel in Great Britain. Lower density populations deeper in catchments tend to be dominated by older, larger and female eel. These can make a potentially high contribution to the total eel breeding stock.

Data on stock and sustained or increased yield

There is much circumstantial historical evidence of decreases in stocks. For example, the number of pre-1086 and pre-1900 records of silver eel traps in the Thames suggest stocks deep in the catchment were very much higher than today (Naismith and Knights, 1993). There is a general consensus that stocks have decreased over the last 15–20 years (McKinnon and Potter, unpublished survey), but quantitative data are lacking.

Best estimates for typical current freshwater stocks (Mann, 1995; Knights et al., 1996; Knights and White, 1997) are:

Population density:	*ca.* 0.3 eel m^{-2} (range 0–12.2)
	ca. 60 kg eel ha^{-1} (range 0–328)
Annual yield:	Range 0–35 kg ha^{-1}

The higher estimates tend to come from productive lowland rivers and still waters. Average potential yield from fresh waters in Great Britain is probably about 10 kg ha^{-1}. Applying this figure to the areas of running and still freshwaters above, estimated total potential sustainable yields are about 500 t and 1,924 t, respectively.

Similarly, if potential yield in saline open waters is estimated to be about 2 kg ha^{-1}.(Table 3.1), total potential sustainable yield is *ca.* 1,000 t, and the total potential from all waters is about 3,424 t .

Historical records of stocking

Stocking of eel has never been carried out on a large or commercial scale.

Data on population dynamics

The only estimates of natural mortality are of $z = 0.37$ per 3 cm length class for eel >30 cm in the Thames Estuary, comparable figures in the literature range between 0.17 and 0.65 (Naismith and Knights, 1990a). Recruitment derivations are discussed below.

Recruitment

Natural mortality of glass eel

For initial recruitment into the Severn/Avon, White and Knights (1994) found the number of immigrant elver and juveniles trapped at the tidal limits represented < 1% of the estimated commercial glass eel catch in the lower estuary. Whilst fishing mortality was important, natural mortality was also probably very high between the time of arrival as glass eel in early spring and resumption of active migration up the long estuary in early- to mid-summer when temperatures rise to 14–16°C (White and Knights, 1997b).

Fishing mortality of glass eel

Some 20–30 t of glass eel are caught annually by dipnet in the Atlantic-facing Severn Estuary and rivers off the Bristol Channel, such as the Parrett and Wye. Increasingly large quantities are coming from other waters, encouraged by rising prices (Moriarty, 1996a,b). The impacts of fishing versus natural mortality are still, however, unclear.

Data on survival of glass eel or bootlace eel after stocking

Some unrecorded casual stocking has occurred in the past, leading to relatively isolated local stocks of larger eel, for example in the upper Thames (Naismith and Knights, 1993). The Environment Agency (formerly National Rivers Authority) has stocked parts of the Lea and other rivers, but few accurate records have been kept or later monitoring studies carried out. Parts of the River Avon were stocked after 1973 with on-grown elver. Local populations could have been augmented by up to 20% as a result (Knights and White, 1997). Data on mortality are not available but estimates for natural stocks in the Thames Estuary (Naismith and Knights, 1993) agree with European figures for stocked glass eel of about 75–80% (Knights and White, 1997). However, mortality estimates are confused by immigration and emigration in open waters.

Recruitment data

Recruitment data are lacking, except some for the Severn and Thames. In both cases, there is strong evidence that barriers (in addition to the effects of low glass eel recruitment from the sea, plus natural and fishing mortality) are reducing the full utilisation of available catchment resources, as discussed above. Eel passes are being fitted to obstructions in the River Avon and there are future plans for the Thames (G. Armstrong, pers. comm.) and the rivers and wetlands of the Somerset Levels. Naismith and Knights (1990a) suggested from z values that 80 glass eel would be required to produce one marketable (34–41 cm) eel in the Thames Estuary, a commercial yield of about 1.5 g per recruit. Such estuarine populations are, however, very mobile.

Data on economics of stocking

No information is available.

Escapement

Escapement of glass eel

Glass eel are exploited in the major Atlantic-facing estuaries of south west England. In the Severn, the number of elver trapped at the tidal head are < 1% of the number of glass eel captured in the downstream commercial fishery, but, as pointed out earlier, the impacts of natural mortality may be very high (Knights and White, 1997). The majority of rivers are not exploited but increasing prices are leading to more intense and widespread fishing for glass eel.

Escapement of silver eel

Very few trap or net fisheries designed specifically for silver eel remain in operation; therefore, escapement should be high.

Number and extent of unexploited water bodies

Commercial eel fishing takes place in many catchments and some estuaries and coastal waters but escapement is probably large. It was estimated above that if all waters supported optimum stocks, the total potential yield of eel from Great Britain waters is in the order of 3,424 t. This is about ten times the estimated commercial yield of 350 t. Thus the species as a whole is not being overexploited, although impacts (especially of glass eel fisheries, plus migration barriers and loss of habitat) may be relatively high in some catchments.

Information on conservation measures

Bye-laws requiring licensing and catch returns for glass eel exist in some areas, such as the Severn–Trent and North Wessex fishery region. They restrict methods to the use of hand-held dip nets of specified size and forbid fishing from a moving boat. All fishery regions require some form of licensing and catch returns for yellow and silver eel fishing and restrictions are placed on the use of *fixed engine* devices (mainly to protect migratory salmonids). There are no standard requirements on minimum size but, for example, minimum fyke net mesh sizes are set in the Thames Estuary fishery to allow the escape of eel < *ca.* 100 g (Naismith and Knights, 1990a). Other local restrictions apply, e.g. fishing may be forbidden because of conflicts with navigation or nature conservation. Otter guards are required in some regions.

References

Aprahamian, M.W. (1988) Age structure of eel, *Anguilla anguilla* (L.), populations in the River Severn, England, and the River Dee, Wales. *Aquaculture and Fisheries Management*, 19, 365–376.

Dill (1993) Inland Fisheries of Europe. *EIFAC Technical Paper* 52 suppl., pp 281.

Knights B. and White E.M. (1997) An appraisal of stocking strategies for eel. In: I.G. Cowx (ed.) *Stocking of Fish into Fresh Waters*. Oxford: Fishing News Books, Blackwell Scientific Publications. In press.

Knights B., White E.M and Naismith I.A. (1996) Stock assessment of European eel, *Anguilla anguilla* L. In: I.G. Cowx (ed.) *Stock Assessment in Inland Fisheries*. pp. 431–447. Oxford: Fishing News Books, Blackwell Scientific Publications.

Mann R.H.K. (1995) *Eel Stock Assessment in the UK*. Report to MAFF, Project No. SF0305. Institute of Freshwater Ecology Project No. T11o63al, IFE, Abbots Ripton, Cambs., England

Moriarty C. (1996a) The European eel fishery in 1993 and 1994. *Fisheries Bulletin (Dublin)* 14, 52 pp.

Moriarty, C. (1996b) Glass eel supply and demand in Europe in 1995 and 1996. *EIFAC/ICES Working Group on Eel* IJmuiden, Netherlands 1996.

Naismith I.A. and Knights B. (1988) Migrations of elver and juvenile European eel, *Anguilla anguilla* L., in the River Thames. *Journal of Fish Biology* 33(Supplement A), 161–175

Naismith I.A. and Knights B. (1990a) Studies of sampling methods and of techniques for estimating populations of eel, *Anguilla anguilla* L. *Aquaculture and Fisheries Management* 21, 357–367.

Naismith I.A. and Knights, B. (1993) The distribution, density and growth of European eel, *Anguilla anguilla* L., in the River Thames catchment. *Journal of Fish Biology* 42, 217–226.

Turnpenny A.W.H. (1989) Field studies on fisheries in acid waters in the United Kingdom. In: Morris et al. (eds) Acid Toxicity and Aquatic Animals. *SEB Seminar Series* 34, 45–65.

White E.M. and Knights B. (1994). *Elver and Eel Stock Assessment in the Severn and Avon*. NRA R&D Project Record 256/13/ST. Bristol: National Rivers Authority (now the Environment Agency).

White E.A. and Knights B. (1997a) Dynamics of upstream migration of the European eel, *Anguilla anguilla* L., in the Rivers Severn and Avon, England, with special reference to the effects of manmade barriers. *Fisheries Management and Ecology* in press.

White E.A. and Knights B. (1997b) An analysis of environmental factors affecting upstream migration of the European eel, *Anguilla anguilla* L., in the Rivers Severn and Avon. *Journal of Fish Biology* in press.

NETHERLANDS

Willem Dekker
RIVO-DLO, Haringkade 1, IJmuiden, The Netherlands

Habitat

Extent of water currently supporting eel stocks

Estuaries The rivers Rhine, Meuse and Schelde flow through the Netherlands into the North Sea, in an intertwining network of branchings and anastomosations. Therefore the estuarine area is hard to define. Brackish areas amount to 500 km^2. The Waddensea is a lagoon-like area of 14,500 km^2 . Because of the inflow of water from the river Rhine directly through lake IJsselmeer and indirectly via the coastal areas of the North Sea, it is brackish in nature. The brackish areas have been greatly reduced by land reclamation, often resulting in freshwater lakes, where the eel populations still strive.

Coastal lagoons No true lagoons exist.

Coastal water Eel are taken as a by-catch in the fishery for brown shrimp. The shrimp fishery has been operated by numerous small boats operating within a few kilometres from the coast; surface area some 50,000 km^2. The nature and extent of the habitat for eel in these areas is unknown; the eel caught might be migrating animals. There are no statistics on the eel catches, but the impression is of a steady decline in the past decade. Additionally, eel are caught as a by-catch in all fisheries on the North Sea. Traditionally, this profit is for the crew members, with the exclusion of the ship owner.

Rivers All surface waters in the Netherlands are connected to the rivers Rhine and Meuse. In the absence of major obstructions in the major waterways, virtually all may be considered to contain eel populations. Surface area of the main rivers is less than 1,000 km^2.

Canals, polders and smaller lakes The accumulated length of ditches in all polders amounts to approximately 300,000 km, corresponding to about 3,000 km^2. The surface area of all fresh water, excluding lake IJsselmeer, is approximately 15,800 km^2. Eel populations exist in all.

Lake Ijsselmeer The surface area of lake IJsselmeer has declined from 34,000 km^2 in 1932 when the lake was closed off from the Waddensea to its present area of 18,200 km^2.

Areas of water inaccessible to eel due to chemical or physical obstruction

Lakes/canals There are no cases of lakes becoming completely inaccessible due to chemical or physical obstructions, but there is reasonable doubt with respect to the efficiency of recruits passing physical (water management) barriers.

Rivers No real obstructions.

Estuaries Many estuaries have been enclosed, but in most cases the immigration of elver has not been blocked completely. There is some evidence that the habitat in enclosed estuaries is more favourable to eel. This includes lake IJsselmeer.

Data on stock and sustained or increased yield

Over the past few centuries, large parts of the Dutch estuaries have been enclosed, enpoldered or controlled by dams. On the one hand, this has certainly reduced the favourable area for the eel but, on the other, previous marine habitats have been transformed into freshwater habitats, still supporting eel populations. Furthermore, it is known that human interference in the estuaries (notably stocking with young mussels) has increased the potential for eel populations.

Eel fisheries are found in all coastal/estuarine areas, but the fishery is nowhere of great economical importance. The volume of the fisheries has gone down over several decades. Following the recruitment failure in the 1980s, yield has fallen rapidly and only a last remnant of the fisheries exists.

In historic times, more than 500 boats (*schokkers*) fished for eel on the river Rhine between Basel and the North Sea. Nowadays, the numbers seem to have stabilised at less than 10 in the Dutch parts, and none in Germany. Catches are not centrally recorded, but certainly do not exceed a few tonnes per boat per year.

The fisheries for eel in polders, canals and smaller lakes has been operated by thousands of fishermen/farmers, supplying anything from a full income to a lifetime hobby. Professionalisation of the fishery sector since the Second World War has resulted in about 400 mostly full-time fishermen. In the past decade this number has fallen to below 300, with an average catch of 1 or 2 t per crew per year, corresponding to some 400 t in total. The Organisation for the Improvement of Inland Fisheries (OVB) keeps records of subsidised elver supplies, but no statistics are kept of the resulting yield in individual water bodies. Stockings vary from nil in areas near the coast to 0.5 kg ha^{-1} per year in remote areas.

The fall in this fishery has been caused by reductions in the accessible area, by land reclamation, 'better' drainage systems preventing the upstream migration, eutrophication and pollution, but also by the fishery falling back compared to the rising average incomes, and recently by shortage of elver supplies.

The eel stock of the IJsselmeer is very heavily overexploited. The yield of silver eel has consequently decreased from 20% to less than 5% of the yellow eel catch, while the annual catch of yellow eel itself has dropped from over 5 kg ha^{-1} to 1 kg ha^{-1}.

The eel stock on lake IJsselmeer is extensively monitored. Data on natural recruitment from the Waddensea (dipnet sampling; Dekker, 1986a, 1996b) and stock surveys on the lake itself (trawl surveys; Dekker, 1996a) correlate well over the years, both showing a sharp decline since the 1980s. However, no man-made stocking is done here.

Historical records of stocking

The elver supply series from the OVB dates from shortly after the Second World War. Over the years, the general trend in stocking has followed the same pattern as the natural immigration; following the natural recruitment failure along the Dutch coast, the rise of the price of glass eel on the international market has prevented compensation by supplementary stockings.

The sampling of the natural recruitment to lake IJsselmeer started in 1938, and was interrupted only for the winter of 1945. The natural recruitment to lake IJsselmeer peaked in the 1960s (and 1970s, absolute maximum in 1963), falling in the eighties to an all-time low in 1991. The rise in recent years has been of negligible magnitude (Dekker, 1996b).

Data on population dynamics

Lake IJsselmeer has been closely monitored. Based on recruitment surveys, commercial catch sampling, independent stock surveys and data series on fishing effort, an accurate picture of the eel stock has been compiled. Most of the research effort has been directed towards the stock dynamics and methodologies for assessment (Dekker, 1996c), not towards estimation of vital statistics of the eel biology (Dekker, 1986b). Estimation of growth has been shown to be tedious, and therefore largely ignored. However, estimates of exploitation rates are available on a yearly basis (Dekker, 1996a), based on routine sampling of the commercial landings. Following a reduction in the fishing effort of nominally 40% in 1989, this has shown that annual fishing rates decreased from 45% to 35% per year (z=0.55, resp. 0.40).

Analysis of stocking densities, growth and survival in small experimental ponds were undertaken in the late 1980s, in order to advise on optimal stocking densities (Klein Breteler et al., 1989). Maximum production of yellow eel was achieved at a biomass of 20–40 kg ha^{-1}, amounting to 19 kg ha^{-1} . However, during this analysis, the supply of elver has fallen to record low values, because of the recruitment failure all over Europe.

Predation by cormorants The quantity of eel eaten annually by cormorants in lake IJsselmeer is negligible: 0.1 kg ha^{-1} compared to 2.5 kg ha^{-1} taken by the fisheries. Cormorants have a much more substantial impact on the fisheries for perch and pikeperch (van Dam et al., 1995).

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

Glass eel fisheries are only allowed when operated on behalf of the Organisation for the Improvement of Inland Fisheries (OVB). Traditionally, the OVB had permission to catch 3 t at one of the entrances to lake IJsselmeer (53°04'N 5°20'E). Following the recruitment failure since the mid-1980s, actual catches on this single location fell well below this quota, resulting in a permit to catch a total of 3 t at six sites along the coast, including the second entrance to lake IJsselmeer (52°56' N 5°03' E). Fishermen on lake IJsselmeer complained that this increased effort took a larger share of their recruitment during the meagre years.

The government decided to allow a catch of 5% of the total immigration to lake IJsselmeer, without knowing how much that amounts to. The fishermen fishing for the OVB estimated the total immigration at 158 tonnes (i.e. 8 tonnes quota would be acceptable), while the RIVO estimates for the same period were only 2 to 5 t (acceptable quota 0.1–0.2 t). The actual catch in that period amounted to 0.6 t. A first attempt to obtain direct estimates of the absolute numbers immigrating, by means of mark–recapture experiments, failed because of methodological problems (Dekker and van Willigen, 1996).

Escapement of glass eel

The fisheries for glass eel traditionally have had only a marginal impact, allowing almost 100% escapement. However, following the recruitment failure in the 1980s, the fishing intensity for glass eel has increased. Views on the impact differ widely (see *Fishing mortality of glass eel* above).

Data on survival of stockings

An experimental study on growth and survival of stocked eel included experiments on glass eel. The combined effect of natural mortality and incomplete recapture amounted to *ca.* 25% per year (Klein Breteler et al., 1989).

Data on economics of stocking

In the 1950s, stocking and yield in 18 polders were analysed, resulting in a recommendation to stock at most 0.5 kg glass eel per ha per year. Gradually, this maximum norm was understood as an optimal norm. No further evaluation has taken place.

Escapement

Number and extent of unexploited water bodies

Polders, lakes and canals are fully exploited. Escapement of silver eel is known to occur, but there is absolutely no clue as to the extent. The minimum legal size is set at a level that allows for fishery on eel at a size approaching that of silver eel, before they escape the fishery. Rivers are not very heavily exploited, catches comprise mostly silver eel and it is likely that large amounts of silver eel escape the rivers.

Information on conservation measures

All legal protection of eel is aiming at optimisation of the yield. The minimum legal size is 28 cm; proposals for 32 cm have been around for nearly 10 years now. The minimum mesh size corresponds to the legal size. There is no nation-wide closed season, but on lake IJsselmeer most eel fishing methods are prohibited from October through April; this is, however, motivated by the by-catch of perch and has only a marginal effect on the eel fishery itself.

References

Dekker W. (1986a) Regional variation in glass eel catches; an evaluation of multiple sampling sites. *Vie et Milieu* 36(4), 251–254.

Dekker W. (1986b) Age reading of European eel using tetracycline-labelled otoliths. *ICES CM 1986*/M:16.

Dekker W. (1991) Assessment of the historical downfall of the IJsselmeer fisheries using anonymous inquiries for effort data. In: I.G. Cowx (ed.) *Catch Effort Sampling Strategies, Their Application in Freshwater Management*. Oxford: Fishing News Books, 420 pp., pp. 233–240.

Dekker W. (1996a) *De visstand en visserij op het IJsselmeer en Markermeer: de toestand in 1995*. (Fish stocks and fisheries on lake IJsselmeer and Markermeer: status in 1995). RIVO report C001/96, 36 pp. Mei 1996.

Dekker W. (1996b) Long-term trends in the glass eel immigrating at Den Oever, the Netherlands. *EIFAC/ICES Working Group on Eel*, IJmuiden, Netherlands, 1996, 24 pp.

Dekker W. (1996c) A length structured matrix population model, used as fish stock assessment tool. In: I.G. Cowx (ed.) *Stock Assessment in Inland Fisheries*. Oxford: Fishing News Books.

Dekker W. and van Willigen J. (1996) *Hoeveel glasaal trekt het IJsselmeer in Verslag van een glasaal-merkproef in Den Oever in 1996*. (How much glass eel immigrate into lake IJsselmeer? Report on a mark–recapture experiment in Den Oever, November 1996). RIVO-DLO report 96012/WD, November 1996, 18 pp.

Klein Breteler J.G.P., Dekker W. and Lammens E.H.H.R. (1989) Growth and production of yellow eel and glass eel in ponds. EIFAC Working Party on Eel, Oporto, Portugal, 1989.

van Dam C., Buijse A.D., Dekker W., van Eerden M.R., Klein Breteler J.G.P. and Veldkamp R. (1995) *Aalscholvers en Beroepsvisserij in het IJsselmeer, het Markermeer en Noordwest Overijssel*. Informatie en Kenniscentrum Natuurbeheer, Wageningen. Nr 19, 104 pp.

FRANCE

Guy Fontenelle[1], Eric Feunteun[2] and Cédric Briand[1]
[1]Laboratoire Halieutique, ENSA, 65 Rue de St Brieuc 35042, Rennes Cedex, [2]Université de Rennes, UMR CNRS 6533, Laboratoire ESNM, 35042 Rennes Cedex,

Habitat

Extent of water currently supporting eel stocks

Estuaries In spite of the lack of a current survey, the extent of French estuaries can be esitmated at about 1,000 km^2. All these habitats are inhabited by eel at some stage. Nevertheless, there is no current monitoring or regular surveying at national scale, except for some estuaries where some scientific work is being carried out (Somme, Arguenon, Vilaine, Gironde, Adour).

Coastal lagoons Almost all coastal lagoons along the Mediterranean Sea support eel exploitation (350 km^2). Most of these areas are accessible for eel, although the water and habitat quality has decreased in recent years because of human activities (sewage, refineries, water management, among others: Cavailles et Loste, 1988).

Reclaimed marshes The reclaimed marshes on the western Atlantic coast are 2,800 km^2 in extent. They contain about 240 km^2 of water, and 40,000 km of ditches. All these areas are accessible to eel and provide for a wide range of habitats except when agricultural practices lead to chemical or physical obstruction.

Lakes The extent of natural lowland and mountain lakes can be estimated as 500 km^2. Hydrodams and drinking water reservoirs cover about 96 km^2. The 3,000 man-made ponds extend over 1,100 km^2.

Rivers and canals.

Average width m	Total length km	Surface km^2
35	11,800	413
10	25,530	255
1	88,000	88
0.5	150,000	75
Total	280,000	840

Most of these areas are accessible by eel, at least in the downstream reaches. However, major dams can obstruct the rivers more or less completely at various distances from the sea (Chancerel, 1994).

Areas inaccessible to eel due to chemical or physical obstruction.

There are no data about the accessibility of these hydrosystems, but most of the mountain lakes, among them the Léman Lake (200 km^2), are inaccessible mainly because of dams and to a lesser degree because of natural obstructions.

Usually, all lowland lakes and ponds are colonised by eel. Some of them, like the Lake of Grand-Lieu (40–60 km^2 according to the water levels) support intensive commercial fisheries.

No precise data are available on river systems. However, annual surveys conducted by Conseil Supérieur de la Pêche (CSP), the State Fisheries Agency, indicate a decreasing density of eel in rivers with increasing distance from the sea (Chancerel, 1994; Legault and Porcher, 1988). This density decline can occur immediately within the estuaries (for example, the Vilaine) and to a greater degree because of multipurpose dams along the system. A rough estimate shows that 10 to 20% of catchments are therefore inaccessible, especially in the Alps, the Pyrenees and the Massif Central.

There is no extensive geographical review on chemical barriers to eel in French freshwater waterbodies except in a few cases where eel may highlight biocontamination by xenobiotics.

Data on stock and sustained or increased yield

Standing crop

An extensive survey throughout France, using electrofishing and the removal method, is conducted each year over 600 sites. The target species is not only eel, but the survey evaluates the interannual development of eel population structure and abundance at a regional and national scale. This survey has shown that at national level, eel densities average between 0 and more than 500 individuals ha^{-1} in France, according to the accessibility and the quality of the habitats (Chancerel, 1994). In all short rivers or lower parts of big river systems which remain accessible to the eel, the species constitutes the major part of fish density and biomass (> 50% : CSP, unpublished data).

At a regional level, for example in Normandy and Brittany, this survey has shown a decreasing trend in eel abundance since 1990. During this period, average biomass has fallen from 70 kg ha^{-1} to 40 kg ha^{-1} in Brittany and from 120 kg ha^{-1} to 60 kg ha^{-1} in Normandy (CSP, unpublished data). This general decrease of the population in Brittany, Normandy and in the Vendée, has also been observed in Mediterranean lagoons (Loste et Dusserre, 1996). Fisheries surveys show that the average catch per fisherman has fallen by about 40% between the 1985–1990 period and the 1991–1995 period in spite of increasing fishing effort. Meanwhile, the average size of silver eel has increased, possibly related to lower densities.

Nevertheless, the accuracy of such a survey is too low to provide for reliable data on the scale of a given watershed. In order to obtain a greater accuracy, more intensive surveys are conducted upon a small number of experimental watersheds. For example, a study in the reclaimed marsh of Bourgneuf (South-Brittany) showed a fall from about 2,000 eel ha^{-1} to less than 600 eel ha^{-1} between 1987 and 1991. The corresponding biomass simultaneously decreased from 70 kg ha^{-1} to less than 20 kg ha^{-1} . This decrease could be due to obstruction to the upstream migration by a dam and to the mortality caused by an elver fishery of about 5 t a year. The total numbers of elver caught represent a density of 50,000 individuals ha^{-1} in the whole catchment. Bad water quality (sewage, agriculture and industries) associated with loss of available habitats (filling of ditches and ponds) can also be involved in the decrease of eel abundance in these man-made waterbodies (Feunteun, 1994).

In 1995 and 1996, a survey conducted in an experimental coastal catchment has shown that the average densities may be about 90,000 ha^{-1} of elver and eel downstream and they drop rapidly to 5,000 eel ha^{-1} in upstream areas because of several physical obstructions to upstream migration. Nevertheless, the average density at the scale of the catchment is very high (5,000 eel ha^{-1}) compared to other rivers, probably because there is no commercial fishery neither in the estuary, nor within the river itself (Guillouet et al., 1995, 1996 ; Feunteun et al. in prep.).

Yield

There is no annual survey conducted in France to assess the overall yield of eel by commercial fishers and anglers. The most recent reviews (Castelnaud and Babin, 1987; Babin, 1991) show that 302 t of eel (including 120 t of silver eel) were caught in 1989 in French inland waters. No data about non professionals are available. Since then, only a few surveys have been conducted within small catchments by CEMAGREF (Bordeaux), especially in the Lake of Grand-Lieu where the eel landings ranged from 22 t in 1991 to 31 t in 1992. The corresponding yield comprised between 0.9 and 8 kg ha^{-1} , of which 4 to 12% were silver eel (Adam & Elie 1994).

A study conducted in 1990 and 1991 (Schaan, 1993) on the estuaries of the Loire and Vilaine has shown that the total captures of eel varied between 75 and 100 t per year and 10 to 20 t per year, respectively. This fishery is conducted by 450 fishermen in the Loire (including 300 non-professionals) and by less than 20 in the Vilaine.

In some reclaimed marshes of the Atlantic coast, in the 1980s about 15 t of eel (mainly silver eel) were caught every year. This represents a yield of 37 kg ha^{-1} . Since then, this resource has declined tremendously and has been reduced by a factor of about 4 : nowadays in the same area (3,600 ha) the yield does not reach 10 kg ha^{-1} .

In the Mediterranean lagoons, once again, the fishery system constitutes the backbone of any survey of eel populations which live in these areas. Unfortunately, very few studies are still in progress (CEPRALMAR, IFREMER).

Most of the yield production data are compiled by the Maritime Statistics System but do not seem reliable and must be considered as underestimates : from 1,264 t in 1991 to 251 t in 1994 (Loste, pers. comm.).The only recent figures which are available come from lagoons near Palavas (Languedoc) and Bages Sigean (Roussillon) that cover about 90 km^2. In both lagoons, the yields and CPUE have decreased by about 40% since 1985 (from 99 to 45 kg ha^{-1} on Bages-Sigean) while the number of fishers declined as well (Loste and Dusserre, 1996).

Some population parameters are available, including age-length keys derived from former validation experiments (Panfili, 1988; Loste et Dusserre, in prep.). The mean length of yellow eel sampled from commercial fisheries (fyke nets) did not change within 10 years (30 cm).

Some water quality problems appear to modify the available habitat for eel: mostly summer dystrophic crises, regression of eel-grass fields, heavy metal and organochlorine pollution (Anonymous, 1992, 1996).

There is a real need for such surveys in France.

Historical records of stocking

No intensive stocking has ever been conducted in French rivers because of a generally favourable natural recruitment. Nevertheless a few rivers of the central regions of France were stocked with bootlace eel until the 1980s. But since then the increasing prices led to cessation of this operation.

Data on population dynamics

Only a few studies have been conducted lately on population dynamics, and only three are now carried out on the continental phases of the life cycles at the scale of wide hydrosystems.

In the marsh of Bourgneuf a study has been in progress on a 36 km^2 area since 1987 by the University of Rennes and the CEMAGREF of Bordeaux. Its main scope is to define the eel habitat relationship with regard to human management and activities. The major conclusions were presented in a PhD thesis (Feunteun, 1994) and in several papers. In this site, the eel distribution mainly depends on the accessibility to the waterbody and has been reduced by various obstructions: sluices and low connectivity of the ditchweb which progressively fills up with mud because of increasing land abandonment. Habitat preference changes during the life cycle: young eel preferring shallowest waters with high vegetation cover whilst the oldest tend to occupy deeper waters. Now, in order to increase the accessibility and habitat quality, experimental areas have been cleared and sluices equipped with fish passes. A survey is in progress to measure the consequences of such development on the eel stock.

In this area, a study concluded that herons consumed on average 6 to 10% of the standing eel biomass. Available and consumed eel population structure was very similar although the biggest eel (>45 cm) were partly neglected (Feunteun and Marion, 1994).

A second study started on the Lake of Grand-Lieu in 1990 to provide data on population dynamics in relation to the commercial fisheries (CEMAGREF of Bordeaux, Ministry of Environment). Part of the results on yields are presented in Adam and Elie (1994) and the full results were to be published in 1997.

The third study began in 1995 in a small catchment of northern Brittany (60 km^2). It aims to measure the effects of the placement of fish passes on two major barriers < 5 km from the sea. The enhancement of the stocks and the population dynamics will be surveyed for at least 3 years. Elver/juvenile and emigrant silver eel trappings will be compared. Mark release studies will be conducted, electric fishing and fyke net surveys will be carried out to assess changes in catchment stocks and population dynamics. First results on the initial stock have been published (Guillouet et al., 1995, 1996) and final results on the dynamics were due for presentation in 1997.

Some studies focused on age determination by otolithometry. They provided growth rate figures, but they emphasised the difficulty in using such techniques because important variations could be observed according to environmental factors such as salinity, latitude, water velocity, etc. (Panfili, 1991; Mounaix, 1992). As an example, in the Vilaine catchments the findings by Mounaix (1992) are reported below.

Age (years)	1	2	3	4	5	6	7	8
Estuary (mm)	126	198	243	302	464	550	610	670
River (mm)	140	235	296	306	335	–	–	–

Promising results have been published (Dufour, 1997) on the possibility of discriminating the sex ratio and related sex dimorphism by testing the growth hormone rate on small eel (as small as 20 cm long and 3 years old). Other physiological works are in progress on absorption of oestrogens by eel in waterbodies commonly used for drinking water. These results deserve greater attention from eel fishery managers and scientists to address the relationship between habitat and sex differentiation.

Recruitment

Natural mortality of glass eel

No precise information is available.

Fishing mortality of glass eel

The commercial fisheries in estuaries remain important. Estimation of fishing mortality is not so easy because of the wide range of fishing methods and limited accuracy of surveys. Recently, the scientific involvement decreased in validating the catch-data at a national scale. Only some estuaries remain under scrutiny.

The national scheme for statistics developed towards a system of logbooks which are filled by commercial fishers and conveyed to a national database. Unfortunately, no distinction among estuaries seems possible (hence, the quality of data has deteriorated compared with previous years). However the French Seawater Authority states that 580 t of glass eel were caught in 1995 (CRTS). These data could be underestimates because no validation has been made using the logbooks from the CIPE.

Surveys have been conducted on some fisheries at a regional scale. In the Vilaine, the total catches, after a decade of decrease in the 1980s (200 t in 1979), seem to have remained constant since 1985 (between 10 and 50 t) for the same fishing effort. Regular surveys of eel and glass eel fisheries by IFREMER stopped recently. However, the Vilaine fishery is being studied by IAV, ENSAR and Commerical Fishers' Association.

Some scientific work (south–west: Adour, Gironde) is still in progress to relate some hydrographic estuarine conditions and glass-eel migration. Unpublished data are also available in Gironde (CEMAGREF Bordeaux) and Adour (IFREMER).

Whatever the estuary, the general trend has been a decrease in fishery production despite an increasing fishing effort for glass eel due to a shift in market demand. After the traditional export to the Spanish consumption market, glass eel are also in demand by Asian dealers for on-growing commercial ventures (Taiwan among others) for sale to the Japanese market.

In common with many other countries, France has become a target for glass eel capture. The first consequences have been an increasing fishing effort mainly by non-commercial fishers who can earn a lot of money (> 2,000 FF kg^{-1}). In Japan, the value can reach 10,000 to 30,000 FF kg^{-1}. This higher pressure may jeopardise all French management efforts.

Data on survival of glass eel or bootlace eel after stocking

No information.

Escapement

Escapement of glass eel

Although this parameter is essential for the upstream dynamics of glass-eel runs, very few sites are currently equipped to monitor escapement toward fresh water. Nevertheless, recent policies on stock enhancement were implemented to encourage escapement upstream (see below).

As a base line, previous data have become available: from nine estuarine eel traps built since 1985, only three remain monitored (Vilaine, Sèvre and Sal). On rivers, 60 fish passes have been settled, among which 18 are equipped with traps and 10 are monitored (*Fish-Pass Co.* pers. comm.). However, all these data have yet to be compiled into a national database to assess an overall escapement towards upstream reaches

Very few published data are available: Sèvre Niortaise (Legault, 1996), Arguenon, Frémur (Fish-Pass and Feunteun, unpublished data), Vilaine where 600 kg of glass eel passed over the dam as compared with 22 t caught by fishers downstream in 1996 (first year functioning) (Briand & Bouisson, 1997). A few devices are also available on upstream dams (more than 200 km from the estuary): Dordogne, Garonne, Vienne (Loire tributary) and surveys have been conducted for long time periods. The migrating population is very different from those of downstream reaches (average size 30–35 cm). Migration is mainly triggered by temperature and water discharge (Legault and Feunteun, 1992 ; Briand & Bouisson, 1997). A general database will soon be available to manage all this information on a national scale.

Information on silver eel escapement

No accurate survey has been conducted on this topic. However, the following assumptions are suggested.

In Mediterranean coastal lagoons, very few silver eel seem to escape because of intensive fishing effort on young eel of less than 25 cm. Therefore, eel very rarely exceed 30 cm long. However, runs of small and young silver eel have been reported which suggests that they may migrate at younger ages (Panfili, 1991).

In most rivers, silver eel fisheries, which were operated mainly on water mills, have progressively been abandoned. But this stage remains a target for some commercial fishers (including the Grand-Lieu Lake, Loire, Garonne, Rhone). The majority of silver eel are theoretically able to escape, but there are currently no reliable statistics on this topic.

Over and above both previous considerations, the main barrier to escapement could be related to the succession of hydrodams (both small and large installations) which lead to high mortalities after passing through the barriers.

Information on conservation measures

Because of the past abundance of eel in French inland waters, successive fishery policies have never really taken stock management of the species into account. Until 1984 eel was considered as a nuisance and was systematically removed from salmonid rivers by the authorities.

Since this date, a law on inland waters enforces dam owners that are settled on *migratory fish rivers* to build efficient fish passes. To encourage such development of migratory fish stock enhancement on all rivers, the Ministry of the Environment has initiated a national funding programme which focuses on several catchments (Somme, Vilaine, Loire, Adour, Rhone). This *fishpass policy* is supposed to be the milestone towards restoration of the species on degraded zones and better management on a watershed scale. Indeed, it allows calculation of natural mortality and escapement at different steps on a river system. On the other hand, there is no significant development of safe devices adapted to downstream migration for silver eel.

The Ministry of the Environment has recently listed eel as a threatened species (*Livre rouge des espèce menacées en France*). A national report on the issues of the Rio Convention also mentions the eel as a vulnerable species to which special intention has to be paid.

Despite this official policy on the eel, there is currently no full-time research worker on the species in France, and research programmes on biology or on stock management are poorly funded.

The management policy of migratory fish recently changed from national to regional entities (COmités de GEstion des POissons MIgrateurs). These committees are composed of one-third representatives of Local Governments, one-third representatives of Administrations and one-third representatives of fishery organisations (commercial and recreational). Two scientific advisors are also members (CSP for inland topics and IFREMER for marine resources). Unfortunately, IFREMER recently stopped working on validating statistics in estuarine zones by surveys.

References

Anonymous (1992) *Etang de Bages-Sigean: 25 ans d'évolution.* Rapport BRL, AIBPA, 45 p.

Anonymous (1996) *Bilan des apports toxiques et trophiques dans les étangs du Narbonnais.* Ministère de l'Agriculture, Région Languedoc-Roussillon, 152 pp. + Annexes

Adam, G and P. Elie (1994). *Etude de la faune ichthyologique et de l'exploitation halieutique professionelle du Lac de Grand Lieu, Loire Atlantique. Premières descriptions et analyses.* Rapport CEMAGREF, Minstère de l'Environment. pp 128.

Babin, D. (1991) *Résultats de l'enquête express 1989 : estimation de la production et du chiffre d'affaires des pêche s professonnelles continentales Françaises (marins pêcheurs exclus).* Plaquette CEMAGREF Bordeaux

Briand, C. and Bouisson (1997). *Suivi des migrateurs sur la Vilaine. Bilan de la première année de fonctionnement des passes à poissons du barrage d'Arzal.* Rapport Institution Interdépartementale de la Vilaine. Conseil Supérieur de la Pêche Bretagne, pp 65.

Castelnaud, G. and D. Babin (1987). *La pêche professionelle aux filets (Anguilla anguilla L.). Méthodes et techniques dans les eaux continentales françaises. Première partie : Les bassins Loire-Allier, Vilaine.* Rapport CEMAGREF Bordeaux, pp 131.

Cavailles, M. and C. Loste (1988). *L'exploitation de l'anguille en Languedoc-Roussillon.* Rapport CEPRALMAR, Montpellier, pp 113.

Chancerel, (1994) La répartition de l'anguille en France. *Bulletin Français Pêche et Pisciculture* 335, 289–294.

Dufour S. (1997) Un exemple de cycle reproducteur sous la dépendance de l'environnement: le cas de l'anguille. *Comptes-rendus Académie d'Agriculture*, 19–28.

Feunteun, E. (1994). *Le peuplement piscicole du marais littoral endigué de Bourgneuf-Machecoul (France, Loire atlantique). Approche méthodologique pour une analyse quantitative de la distribution spatiale du peuplement piscicole et de la dynamique de certaines de ses populations.* Thèse Université Rennes, pp 1,240.

Feunteun E. and L. Marion (1994)Assessment of grey heron predation on fish communites: the case of the largest European colony. *Hydrobiologia* 279-280, 327-334.

Feunteun E. C. Rigaud and A. Legault (1994). Le marais doux endigué de Bourgneuf-Machecoul: premiers éléments du connaissance du peuplement piscicole; relation ichthyofaune-habitat; mise en évidence de problèmes majeurs de gestion. *Revue des Sciences de l'Eau* 5 (4), 509-527.

Fontenelle, G. (1991). Age and growth of eel on an European scale: a critical review. EIFAC Working Party on Eel, Dublin, Ireland 1991. pp 33.

Fontenelle, G. and B. Mounaix (1993). *L'anguille (Anguilla anguilla) espèce traceur de certains polluants dans le bassin versant de l'Elorn et en Rade de Brest. Etude de faisabilité.* Plan d'amélioration de la qualité des eaux de sauvegarde et de restoration de l'écosystème marin en Rade de Brest. Rapport Contrat Communauté Urbaine de Brest/Ecole Nationale Supérieure Agronomique de Rennes. pp 50.

Guillouet, J., E. Feunteun and A. Legault (1995). *Etat initiale de la population d'anguilles du bassin versant du Frémur avant aménagement de passes à poissons sur des obstacles majeurs à lamigration anadrome.* Rapport Fish Pass - Fédération Départmentale AAPMA, Ile et Vilaine, pp 34.

Guillouet, J., E. Feunteun and A. Legault (1995). *Etat initiale de la population d'anguilles du bassin versant du Frémur avant aménagement de passes à poissons sur des obstacles majeurs à lamigration anadrome. Premier suiviv de la migration anadrome et catadrome* Rapport Fish Pass - Fédération Départmentale AAPMA, Ile et Vilaine, pp 23.

Legault, A. (1994). Etude préliminaire du recrutement fluvial de l'anguille. *Bulletin français de Pêche et de Pisciculture.* 335, 33-41.

Legault A., (1996). Colonisation dynamics of catchment area by eel: characterisation of migrating populations in a free access river. *Communication Colloque Ecohydraulique 2000*, Quebec 1996.

Legault A., (1996) Colonisation dynamics of catchment area by eel: characterisation of migrating populations in a free access river. *Communication Colloque Ecohydraulique 2000*, Quebec 1996.

Legault A. and E. Feunteun, (1992) *Etude de la migration estivale des anguilles au barrage de Golfech sur la Garonne.* Rapport Fish Pass / Magado, 25 pp.

Legault A. and J. P. Porcher (1988) Distribution des populations d'anguilles dans les bassins versants de la Bretagne. *EIFAC Working Party on Eel.*

Loste, C. and K. Dusserre (1996) *La pêche sur l'étang de Bages-Sigean.* Rapport CEPRALMAR, Montpellier, 100 pp. + 10 annexes.

Mounaix B. (1992) *Intercalibration et validation des méthodes d'estimationde l'âge de l'Anguille Européenne (Anguilla anguilla).* Doctorat Halieutique, Ecole Nationale Supérieure Agronomique de Rennes. 146 pp.

Panfili, J. (1991). *Etude des populations d'Anguilles (Anguilla anguilla) des lagunes du Languedoc et de Camargue: méthodes de lectures d'âge et comparison des croissances.* Thèse Doctorat Université Scienes et Techniques Languedoc, Montpellier, pp 456 + 11 annexes.

Schaan O. (1993) *L'exploitation des anguilles sub-adultes (Anguilla anguilla) dans les estuaires de Loire et de Vilaine : méthode d'estimation des captures par âge.* Doctorat Halieutique, Ecole. Nationale Supérieure Agronomique de Rennes. pp 155 + 5 annexes.

Ximenes, M. C. (1986). *L'Anguille en Méditerranée française : aspects écobiologiques et halieutiques.* Rapport du Ministère de la Mer / CEMAGREF, Montpellier-ALA, France. pp 166.

PORTUGAL

Maria da Assunção Santos
Instituto de Ciências Biomédicas de Abel Salazar, Universidade do Porto, Lg. Prof. Abel Salazar 2 , 4000 Porto, Portugal

Habitat

Extent of water currently supporting eel stocks

Estuaries Areas of estuaries were rarely available. The Tejo estuary, the largest in western Europe, measures 320 km^2 and the Minho estuary is 5 km^2. Potentially, all estuaries are inhabited by eel populations and their densities seem to depend on the level of pollution.

Coastal lagoons Various lagoons exist at a short distance from the coast, communicating with the sea permanently or, in certain seasons of the year, through natural or artificial entrances. Six lagoons of a total area of 225 ha are located within 6 km from the sea, on the coastline between Mira and Quiaios, in the central region. Another five coastal lagoons exist, including Lagoa de Óbidos, the largest in the country, with a length of 5.5 km and a maximum width of 1.5 km. Fishing activities take place in the larger lagoons where eel are caught by trap, long line and rod-and-line.

There are two important estuarine coastal lagoon systems in Portugal, the Ria Formosa with an area of 17 km^2 at low spring tide and 84 km^2 at high spring tide, and the Ria de Aveiro with an area of 43 km^2, connected to the sea by a 470-m wide canal. Eel fisheries are well established but unquantified in Ria de Aveiro.

Lakes There are no substantial lakes in Portugal. Small mountain lakes in the Serra da Estrela (Seca, Redonda, Escura and Comprida, and the Manteigas lagoons) should be mentioned, but eel have never been recorded in them.

Coastal water Scuba divers report the presence of eel at breakwaters or jetties made of quarry rocks. There is no targeted fishery for eel, but they occur in by-catch.

Rivers/canals The 12 largest catchment areas total 79,742 km^2, almost equal to the total surface area of Portugal. The total length of the 65 main rivers is about 6,000 km. The reservoir areas of the largest Portuguese dams cover 266 km^2, but eel populations, if they occur at all, are very sparse.

Areas of water inaccessible to eel due to chemical or physical obstructions

Lakes/lagoons In general, coastal lagoons as typical habitats for eel populations, show signs of accelerated eutrophic processes due to the introduction of wastewater effluents.

Regular opening of the canals which communicate with the sea, dredging activities to avoid accumulation of sand, and the control of pollution, could lead to high densities of eel.

Rivers/canals Fishing resources and the distribution of eel have been affected by the construction of hydro dams, mainly since the 1950s. Besides a huge number of small dams, 100 large impoundments exist in Portugal. Some of them are equipped with fish ladders and other similar devices (Carrapatelo, Crestuma-Lever, Pocinho, Régua, and Valeira, located in the River Douro, Penide in the River Cávado and Touvedo in the River Lima) (Portuguese National Committee on Large Dams, 1992). Their ineffectiveness, bad design and unsuitable or non-functioning fishways, are reasons why some of the migrating species have disappeared (Valente, 1993). In some rivers, on the downstream side of the impoundments and close to the sea, the eel is subject to intense fishing. Approximately 70% of total Portuguese catchment areas are inaccessible to glass eel.

Data on stock and sustained or increased yield

Preliminary conclusions on the abundance and distribution of eel in the Rio Minho during 1988, based on results of an experimental fishery with fyke nets and electrofishing, indicated that the estuary was inhabited by smaller eel than the upper parts of the river (Antunes and Weber, 1990).

In the upper zone of the Tejo estuary, a study on feeding habits of the eel provided the following length frequencies (Costa et al., 1992):

Sampling sites	Salinity	<20 cm	20-30 cm	>30 cm
V. F. Xira	8–25%	30%	50%	20%
Alcochete	0–14%	20%	58%	22%

In a small stream below the Belver dam on the River Tejo, 200 km from the sea, the median size of eel captured by electrofishing was 23.3 cm. The density reached 0.9 individuals m^{-2} or 22 kg ha^{-1} (Costa et al., 1991).

A study in the exploited coastal lagoon Ria de Aveiro revealed that 94% of a sample of 1,170 eel belonged to age groups 0 to 2. This lagoon system was inhabited by a young eel population (Gordo and Jorge, 1991).

Historical records of stocking

Eel stocking has probably never taken place.

Data on population dynamics

No information.

Recruitment

Natural mortality of glass eel

No information available.

Fishing mortality of glass eel

Glass eel are intensively fished in almost all Portuguese estuaries, that of the River Minho being the most important. Yields from Portugal and Spain, according to official data, decreased from a peak of 50 t in 1980/81 to 8 t in 1987/88 and less than 10 t thereafter (Antunes and Weber, 1996). A slow recovery began in 1994.

Escapement of glass eel

The escapement of glass eel is limited in all the major hydrographic areas by impoundments close to the estuaries. In the River Douro, with the largest catchment area of the Iberian Peninsula (97,682 km^2), the first impoundment is located only 22 km from the estuary. In relation to its length within Portugal (330 km), only 6.7% is available for eel colonisation.

Escapement

Number and extent of unexploited water bodies

Close to the estuaries and on the downstream side of the dams, eel are fished in all the rivers. Fishing is largely recreational and therefore possibly inefficient and allowing substantial escapement. The major coastal lagoons and one of the estuarine coastal lagoon systems (Ria de Aveiro) are intensively fished and, in the few cases where the fishery has been studied, give a strong indication of growth overfishing and extremely low escapement. Smaller coastal lagoons and the larger estuaries are less intensively exploited.

Information on conservation measures

The Portuguese fishery regulations of 26 November 1981 (Dec. Lei 316, Art 55º) permit the use of a *hamen net* or *stow net* for catching glass eel between November and April, only in the 75 km of the international Minho (Weber, 1986). In the rest of the country fishing for glass eel is allowed only with dip net, from the river banks, and is confined to the period October to April. The diameter, depth and mesh size of this gear are also established by law. Since 1985, fishermen are required to apply for fishing licences and to report their catches (Domingos, 1992).

Fyke nets are allowed only for 3 months, September to November, whereas bottom long lines are permitted all the year round.

An official publication classifies the eel as a commercially threatened species in Portugal (SNPRCN, 1991).

References

Antunes C. and Weber M. (1990) Abundance and distribution of eel (*Anguilla anguilla*) in the Rio Minho. *International Revue der Gesamten Hydrobiologie* 75 (6): 795.

Antunes C. and Weber M. (1996) The glass eel fishery and the by-catch in the Rio Minho after one decade (1981–1982 and 1991–1992). *Archiwum Rybactwa Polskiego* 4 (2): 131–139.

Costa J.L., Almeida P.R., Assis C.A. Moreira F.M. and Costa M. J. (1991) A study of methods of estimating the size of eel populations in small streams. *Irish Fisheries Investigations*, Series A 36: 68–69.

Costa J.L., Assis C.A., Almeida P.R., Moreira F.M. and Costa M.J. (1992) On the food of the European eel, *Anguilla anguilla* (L.), in the upper zone of the Tagus estuary, Portugal. *Journal of Fish Biology* 41: 841–850.

Domingos I.M. (1992) Fluctuation of glass eel migration in the Mondego estuary (Portugal) in 1988 and 1989. *Irish Fisheries Investigations*, Series A, 36: 1–4.

Gordo L.S. and Jorge I.M. (1991) Age and growth of the European eel, *Anguilla anguilla* (Linnaeus, 1758) in the Aveiro Lagoon, Portugal. *Sci. Mar.* 55 (2): 389–395.

Portuguese National Committee on Large Dams (1992). *Large dams in Portugal.* Lisbon, 276 pp.

SNPRCN (Serviço National de Parques, Reservas e Conservação da Natureza) (1991) *Livro Vermelho dos Vertebrados de Portugal.* Vol.II Peixes dulciaquicolas e migradores. 55 pp.

Valente A. (1993) Impactes de emprendimentos hidroeléctricos sobre as comunidades piscícolas. *Recursos Hídricos* 13 (3): 9–14.

Weber M. (1986) Fishing method and seasonal occurrence of glass eel (*Anguilla anguilla* L.) in the Rio Minho, West coast of the Iberian Peninsula. *Vie et Milieu* 36 (4): 243–250.

SPAIN

Maria José Lara
c/. Cabrales N°84 9°C, 33201 Gijón Asturias, Spain

Habitat

Extent of water currently supporting eel stocks

Estuaries Dill (1993) lists 60 rivers of > 60 km in length. The estuaries of all 60 have eel populations.

Coastal lagoons The main coastal lagoons are on the Mediterranean coast: Albufera (Valencia) and Mar Menor (Murcia) and in the Balearic Islands: S'Albufera (Mallorca) and Albufera des Grau (Menorca). Eel stocks exist in all. Catch data are scarce and biased.

Eel and glass eel fishing take place in Albufera, having 20 km^2 of lagoon plus 19 km^2 of rice field. It is a very important ecological system. Mar Menor is a hypersaline lagoon (45–52%) with a surface of 132 km^2. Eel fishing takes place from October to May, but there is no glass eel catch.

Lakes A large proportion of the lakes are in Asturias, in mountain places. In other regions, the lakes are not developed for fisheries and many of them are inaccessible to eel. In Astuarias, lakes are in mountain areas, over 1,000 m above sea level and most of them over 1,500 m. There are no references to fish populations in these lakes and data on extent are only available for the biggest (18, 7, 10, 12 and 8 ha, total 55 ha). There are no references to the presence of eel. In lakes communicating with the Narcea–Nalon basin it is unlikely that eel exist as their migration is blocked by hydrodams.

Coastal waters The Astuarias coast measures about 300 km and it is known by sport fishermen that the eel is a common species (but not appreciated) in several places, mainly inside ports and near river mouths. Eel is not exploited.

Rivers/canals Spain has seven main rivers with a total catchment area of 397,654 km^2 . In addition, in the north of the country there are a great number of short rivers (mountains are very near the coast) very important in water discharge, and having a total catchment of 56,487 km^2, of which 4,827 km^2 are for the Narvea–Nalon basin. The Pyrenees rivers have a catchment of 16,600 km^2. Dill (1993) gives the number of rivers and streams as 1,800 with a total length of permanent rivers of 72,000 km.

Areas inaccessible to eel due to chemical or physical obstructions

Estuaries There are no studies on eel populations in Spain in recent years, but it is clear that there are eel in almost all the estuaries. The exception could be some river mouths and estuaries with a high level of industrial contamination, such as several cases in the Basque country, or some rivers degraded by agricultural pollution or tourist use, as happens in some Mediterranean areas. In nearly all estuaries glass eel fishing takes place.

Coastal lagoons There are no obstructions to eel migration into coastal lagoons, though in all cases the surface area of the lagoons has been reduced by agricultural or tourist use. For this reason the water quality has deteriorated.

Lakes Access to the majority of lakes is prevented by their distribution at high levels in mountain ranges.

Rivers/canals (a) Northern rivers: There are several main rivers and a large number of small ones. The whole catchment is 40,252 km^2 including the Narcea–Nalon basin, and the Mino (natural border between Spain and Portugal) has a catchment area of 16,235 km^2 in Spain. In Asturias the Narcea–Nalon basin has a series of obstacles, mainly in the Nalon branch, that together with pollution from coal mines probably caused the disappearance of eel. In the Narcea branch eel is present in almost all zones of the river except in mountain areas.

(b) Mediterranean rivers: The main rivers which discharge to the Mediterranean Sea are:

River	Length km	Catchment area including reservoirs km²
Ebro	910	85,500
Jucar	498	42,989
Segura	325	18,870

There are also a number of small rivers for which no information is available.

In the Ebro, due to the presence of a number of important dams, the eel is present only in the delta and lower part. For Jucar and Segura, prolonged drought and important hydrological works have seriously degraded the rivers and it is possible that the eel has disappeared from most of the areas, being present only in estuaries or river mouths.

(c) Atlantic rivers: These are shared with Portugal in which the estuaries are situated. The rivers (other than the Mino) are:

River	Length km in Spain	Catchment km² in Spain
Duero	920	79,300
Tajo	1,007	55,769
Guadiana	78	48,556
Guadalquivir	657	54,970

The Duero and Tajo rise in Spain and meet the sea in Portugal. In both cases there are many big dams, the first within Portugal, and in Spanish territory the eel has disappeared. The Guadiana forms the southern border with Portugal. The estuary is shared by the two countries, a margin for each one. It is likely that dams have the same effect as in the Duero and Tajo. No information is available for the Guadalquivir.

Eel are present in all the northern rivers except in the biggest where it is possible that they have disappeared from the major parts in some cases due to dam constructions and in others due to pollution. In the Mediterranean rivers, eel have disappeared from the middle and higher parts due to dams and pollution (industrial, agricultural and tourist problems). In Atlantic rivers, the eel has disappeared from the Spanish zone mainly because of dam construction and eel populations are largely confined to the Portuguese zone. No information is available about the eel population in southern Spain, but they exist in the lower parts.

Data on stock and sustained or increased yield

No studies have been carried out on stock and yield of yellow and silver eel.

Historical records of stocking

There are no available data on stocking in Spain.

Data on population dynamics

Work is in progress on eel population dynamics in the Narcea basin, including such parameters as growth and age. Lobon–Cervia and Carrascal (1992) studied eel silvering in a Cantabrian river and showed that silver eel are found between September and March, and range from 28 to 35 cm. Lobon–Cervia et al. (1995) in the same river showed that mean eel size decreased upstream and showed marked seasonal and annual fluctuations. In this river population was mainly composed of males. They gave values of z in four tributaries of the same river ranging from 2.04 to 2.89.

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

There is a strong tradition for glass eel consumption in Spain and it is the main consumer in Europe. It is known that glass eel is fished at all the river mouths and estuaries, mainly on the North Atlantic and southern rivers.

In Asturias there are at least 12 estuaries where glass eel are fished. The only data available refers to the Nalon estuary and the area in which fishing takes place is 2 km². Catch figures are available from 1952 onwards. Catches from 1952 to 1972 varied between 10 and 20 tons without a trend. A dramatic increase began in 1973, to a peak yield of 60 t in 1977. It returned to the earlier levels in 1984 and fell even lower in the 1990s but without a marked increase in fishing effort (Lara, 1993, 1994). In the 1990s very poor catches have been made in comparison with 1970s and 1980s when catches began to decrease. The season 1995/96, with less than 6 t, has been the poorest season in all the Nalon fishery history. Recent comments show that the current season, 1996/97 has been very similar to its predecessor.

Year	Catch t
1990	7.2
1991	10.2
1992	9.7
1993	9.9
1994	12.5
1995	5.9

On the whole northern coast of Spain, from Galicia to the Basque country, glass eel are fished in all river mouths and estuaries. On the Mediterranean coast, glass eel are fished in the Ebro delta and in the channels entering the coastal lagoons. In the south of Spain, glass eel are fished in the Guadalquivir estuary.

Escapement

Escapement of glass eel

In practically all the rivers of northern Spain, glass eel are fished, though they may be completely unexploited in some small rivers and streams. In Mediterranean areas (rivers and coastal lagoons) glass eel and eel are fished but the exploitation level is unknown.

Evidence for glass eel over-fishing is not very clear, because in the north, where there has been glass eel fishing from the beginning of the century, eel populations are at present better than in other areas where the species has disappeared, even though recruitment has diminished in the last decades as in all parts of the distribution area.

Conservation measures

Spain is divided into several regions and each one has its own legislation on fishing. For glass eel there exists a legal season and it is necessary to hold a licence. But, owing to the high prices of the product, *unlicensed* or *sport* fishermen exploit glass eel in river mouths and estuaries, because little or no control exists. The same happens with dealers who buy glass eel from anyone and they are also outside control. In addition, now that glass eel are targeted by Asian dealers, fishing effort has increased even more, mainly by non-professional fishermen, who can earn a lot of money. This could damage any conservation measure.

References

Dill W.A. (1993) Inland Fisheries of Europe. *EIFAC Technical Paper* 52 suppl.

Fernandez-Delgado C. (1987) *Ictiofauna del esturio del Guadalquivir: su distribucion y biologia de las especies sedentarias*: Tesis Doctoral. Universidad de Cordoba.

Lara M.J. (1993) The glass eel fishery in Asturias (NW Spain) and biological studies on eel. *EIFAC Working Party on Eel. Olsztyn, Poland*, 1993.

Lara M.J. (1994) Catch statistics, capture methods, size and development stages of glass eel in Asturias (Northwestern Spain). *Bulletin of the Sea Fisheries Institute (Poland).* 1 (131), 31–39.

Lobon-Cervia J. and Carrascal M. (1992) Seasonal timing of silver eel *Anguilla anguilla* (L) in a Cantabrian stream (North Spain). *Archiv fuer Hydrobiologie* 125 (1), 121–126.

Lobon-Cervia J., Utrilla C.G. and Rincon P.A. (1995) Variations in the population dynamics of the European eel *Anguilla anguilla* (L.) along the course of a Cantabrian river. *Ecology of Freshwater Fish* 4, 17–27.

ITALY

Eleonora Ciccotti
Dipartimento di Biologia, Laboratorio di Ecologia Sperimentale ed Acquacoltura, Università 'Tor Vergata', Via della Ricerca Scientifica, 00133 Rome, Italy

Habitat

Extent of water currently supporting eel stock

Estuaries The estuaries of the main (> 60 km total length) rivers number 29, to which about seven minor estuaries have to be added. Eel are probably present in most of them, but professional eel fisheries (yellow and silver) are confined to a small number. Glass eel ascent, on the contrary, has been ascertained by experimental fishing in many main and minor rivers (AAVV, 1988), and professional glass eel fisheries take place in a higher number, and in many channel mouths as well, owing to the fact that this kind of fishery is often *mobile*, fry fishermen moving from site to site in different regions with equipped trucks to catch and transport glass eel, besides the juveniles of other eurhyhaline species.

Coastal lagoons Most of the yield of yellow and silver eel fisheries comes from *extensive culture* in the coastal lagoons which cover around 1,500 km^2, of which approximately 610 km^2 are exploited at present. Of the exploited area, about 300 km^2 are located in the upper Adriatic and 120 in the Po delta, the rest being scattered in Apulia, Campania, Latium, Tuscany, Sicily and Sardinia (Ardizzone et al., 1988).

Lakes Large freshwater lakes, greater than 5 km^2, in Italy number over 370 and have a total area of about 2,045 km^2 (Dill, 1990). The number of Italian lakes employed in fisheries is about 150, of which 107 have an area larger than 20 ha (De Angelis, 1986), providing fisheries for both cold- and warm-water species.

On the whole, the presence of eel is known, from literature or other sources, in about 1,200–1,300 km^2, including all the large Alpine lakes of northern Italy and the volcanic lakes of central Italy. In some of them eel is the most important commercial species and yields are sustained by means of restocking. Furthermore, 300 km^2 of hydro dams and 1.5 km^2 of irrigation reservoirs are present (De Angelis, 1961).

Coastal waters It is believed that there is no significant population of marine-dwelling eel.

Rivers/canals The number of rivers in total is about 98, but main rivers, those greater than 60 km, number 45, 16 of which are tributaries to others. The total length is 7,782 km and water surface area 78 km^2. The total catchment area amounts to 231,000 km^2. To this total, about 30,000 km, about 30 km^2 , of artificial canals must be added (De Angelis, 1961). Some, such as those which link the Sesia, Ticino and Po rivers to supply irrigation water, aid in the distribution of fish, and certainly of eel.

Eel are present in most main and minor rivers, but production by riverine fisheries is probably negligible at present, as it is never mentioned in official statistics. Eel professional fisheries are practised in not more than four or five rivers, and concern only limited portions of rivers and some canals. Sport fishing could account for a certain amount of riverine catches.

Areas of water inaccessible to eel due to chemical or physical obstruction

Lakes Even if lakes exploited for fisheries are about 40% of the total, eel are probably present sporadically in most basins, owing to migrations through tributaries or to methodical or occasional restockings. An exception is perhaps the case of the small, deep, high altitude Alpine lakes.

Rivers/canals As with the lakes, eel are probably present in all the Italian riverine system, but undoubtedly abundance progressively falls with increasing distance from the sea, owing to the presence of numerous dams, most of which are not supplied with fishways or have inadequate fishways, and are therefore impassable. It can be roughly estimated that 60% of the rivers are inaccessible to eel. To enhance stocks, rather than to sustain yields, restockings are carried out by Province or Regional Administrations. Eel are scarce or completely absent from the upper reaches of rivers and from an unspecified number of mountain torrents.

Data on stock and sustained or increased yield

Many data on stocks and sustained yields in the literature refer to coastal lagoon populations. Italian extensive culture in coastal lagoons is, rather than a culture system, a special case of management. North Adriatic lagoons represent nearly 50% of the total exploited surface of lagoon environments. In this region, the traditional *vallicultura* is carried out in the *valli*, sectors of lagoon enclosed by embankments whose main structural features are sluice gates, internal canalisation, fish collecting and wintering basins and *lavorieri*, the traditional fish barriers (Ardizzone et al., 1988). Overall yield from the extensive sector in the North Adriatic region seems to amount to 900–1000 t.

Cumulative data from some North Adriatic lagoons based on samples of 234 male and 1,746 female silver eel in 1976 showed that males ranged from 36 to 54 cm and from 70 to 245 g, with an average length of 43.2 cm and became silver between 3 and 9 years old. The females ranged from 39 to 100 cm and from 130 to 2,400 g, with an average length of 59.6 cm, becoming silver from 3 to 14 years old. Yield from seven lagoons ranged from 6 to 25 kg ha^{-1} (Rossi and Colombo, 1976).

Differences in environmental conditions, and therefore in trophic state, can account for differences in growth, while variations in yield among lagoons are due to the fact that each *valle* has its own management strategies: fish densities, fry stockings, fishing effort can differ from lagoon to lagoon. Furthermore, in the 1970s in the North Adriatic region, eel production declined as a consequence of *argulosis*, and infection rates varied among lagoons.

For the Comacchio lagoons (North-Adriatic), biomass 76 kg ha^{-1} and production 36 kg ha^{-1}, were estimated for the period 1974–1976 by Allen's method. The yield observed in the above period was 19 kg ha^{-1}. It was suggested that the Valli were underexploited in the above mentioned period and the author discussed various possibilities of a different environment management for a thorough exploitation of the natural resources (Rossi, 1979).

Rossi et al. (1987–1988) studied the Comacchio lagoon 10 years later and found dramatic changes in eel population and density. This did not influence either the eel's growth rate or survival rate, estimated by means of the mark–recapture method at between 77 and 90% for eel of age class 2 and up, while the sex ratio was shifted from 3:1 to 9:1 in favour of the females. Because of the decrease in recruitment, the estimated annual production (from 13 to 25 kg ha^{-1}) was lower than that previously calculated.

In other Italian lagoon environments, such as the brackish water coastal lakes of central and southern Italy and the Sardinian *ponds*, management strategies are simpler, and yield comes primarily from artisanal fisheries inside the lagoons all the year, rather than from seasonal catches at the fish barrier. A typical model of Italian lagoons other than the North Adriatic ones cannot be defined, since widely differing conditions may exist in each case. Artisanal fisheries yields in lagoons amounted to 473 t in 1993, 191 of which were from Sardinian *ponds* (Istituto Nazionale di Statistica, 1996).

Sardinia is the Italian region with the largest number of coastal lagoons and, although most of them are small, they have an overall area of around 100 km^2. Environmental and fishing resource management are extremely variable. In general, the lagoons are not very deep, < 1 m, and salinity varies. Some problems of eel fishing in hypersaline coastal lagoons were examined by Rossi and Cannas (1984) by an analysis of eel catches in Porto Pino, three connected basins of about 441 ha in southern Sardinia, where the average annual catch of eel, about 19 kg ha^{-1}, was roughly half of the total catch and over 65% of the gross economic return from these ponds.

The parameters of eel population dynamics and exploitation rate were estimated from the number and weight of eel in each of three trade-weight categories, into which the catch was divided each day as required by the market , and from examination of random samples, from each stratum, for age and sex. In the particular case of Porto Pino ponds, the estimated yield of 12 g per recruit seemed to indicate that the stock of eel was under-fished. The authors observed that catch is not proportional to the intensity of effort, but depends on environmental conditions, such as lunar phase, presence of winds and bad weather. The catch could be increased by using a larger number of fyke nets, but should not be sought by extending the fishing period, because that might harm the juveniles of other commercially exploited species. It was then suggested that yield optimisation could be achieved by concentrating the maximum effort in the period of silver eel migration.

Data are available also for the Tortolì lagoon, 259 ha, in eastern Sardinia, from 1957 to 1978. Production was affected by a series of management actions, such as the closing of the freshwater canal in 1959 or the closing of a canal conveying fry in the lagoon in 1964. Restocking operations, with fry caught in the surrounding coastal areas, were carried out in the period 1969–1971, but later suspended when fry fishing was forbidden. Eel represented about 30% of total catches in former years: eel yield amounted to 120–130 kg ha^{-1} in the period 1957–1964, but dropped to an average of about 40 kg ha^{-1} from 1965 (Ardizzone et al., 1988).

The fish catch and samples of commercial fishes caught in the Acquatina lake, a brackish water coastal lake of 45 ha in the south-western Adriatic coastal region of Apulia, were studied by Rossi and Corbari (1982). The fish population was mainly formed by species reproducing in the sea: 33% are silver eel. The eel grew slowly, probably because of their high relative abundance. The shortage of the prey-species in the intermediate trophic levels, due to the rocky bottom which covered one-third of its area, was also limiting. Yields ranged from 4.6 to 17.6 kg ha^{-1} over the period 1976 to 1979.

In the Lesina lagoon, 51 km^2, in the Southern Adriatic, the global production trend for all fish gradually decreased from an average of 80–90 kg ha^{-1} in the 1950s–60s to about 30 kg ha^{-1} in the 1970s, showing a partial recovery in the 1980s thanks to artificial stocking of fry. The eel constituted 40% of the catch but has now fallen to about 23%, i.e. about 9.4 kg ha^{-1} . The change has not only been quantitative: eel and grey mullet have been reduced in favour of other species that can reproduce inside the lagoon (Rossi and Villani, 1980).

The trophic status of most Italian lagoons is at present increasing because of inputs of organic pollutants. This can lead to increasing trends in fish yields, but may also cause dystrophic status with periodical mass mortalities. This has been the case in the Orbetello lagoon in Tuscany on the central Tyrrhenian, which has a total area of about 27 km^2 and an average depth of 1 m. The general management of the lagoon has steadily improved, by means of dredging of the bottom, building of modern fish barriers and seawater pumping during critical periods. A strong increase in eutrophication has progressively taken place, which has perhaps positively affected production, but on the other hand has caused more and more frequent dystrophic crises with high fish mortalities. The catch of all fish has increased, from an average 100 kg ha^{-1} in the 1960s to about 170 kg ha^{-1} average, of which 48% was represented by eel, > 80 kg ha^{-1} during the period 1971–1982. Occasional decreases were due to massive losses coinciding with dystrophic crises. Artificial fry stocking is rather limited and scarcely important for the yield (Ardizzone et al., 1988).

An environment in which management has improved eel production is the Monaci coastal lake, in Latium on the central Tyrrhenian. This is one of the four lakes that are the remains of the Pontine Marshes and has an area of 95 ha and a mean depth of about 1 m. Salinity ranges between 17 and 38%. Communication with the sea is not direct: it took place in the past through a heavily polluted channel that led up to a few years ago to frequent dystrophic crises both in winter and summer. The first were linked to phytoplanktonic blooms, the later ones to macrophyte blooms, both causing mass losses of fish. Twenty years ago, in 1979, the management that took over the lake blocked the inlets from the channel and provided the necessary water input by pumping from a nearby channel connected to the sea.

The fish barrier located at the outlet channel is ineffective, thus excluding the principal gear used for silver eel fishing. Gears most commonly used are winged fyke nets, used singly or in groups, usually installed along the shores with a few groups in the middle of the lake, up to a maximum of 100 at a time. The annual fishing effort on eel is about 250 days/year, divided in two periods, October–January for silver and March–July for yellow eel.

Production data are available for a few years (Ardizzone and Corsi, 1985). Following the beginning of restocking with glass eel at a density of 1 kg ha^{-1} in 1979–80, the yield observed in 1983 had increased to 112 kg ha^{-1}. In 1981, the seeding was performed with small eel of 6–9 g, and production rose in 1984 to 324 kg ha^{-1}. No recent data are available.

On the whole, eel yields in coastal lagoon environments depend primarily on environmental quality and then on recruitment. These in turn influence fish densities and management strategies with reference to fishing effort and restocking. Thus, observed yields are extremely variable, from the 6 kg ha^{-1} observed in Comacchio in recent years (Rossi et al., 1987–1988) to the 324 kg ha^{-1} obtained in the Monaci coastal lake in 1984 by means of restockings (Ardizzone and Corsi, 1985).

Eel stocks in inland waters, and in particular in lakes, are based completely on restocking, and this is particularly true in the case of artificial lakes. De Angelis (1986) reports that about three quarters of the annual global catch in inland waters (estimated to be about 10,000 t) comes from the 17 main lakes of north and central Italy, for a total area of about 1,169 km^2, with eel accounting for 50% of the total, some 5,000 t. Other statistics, however, give lower figures: annual eel catches in inland waters decreasing from 1,000 to 449 t in the period 1970–1983, representing from 20 to 8.5% of total catch (Dill, 1990), and average 340 t in the period 1989–1993, ranging from 3.9 to 5.2% of total inland water catches (Istituto Nazionale di Statistica, 1996).

To make a qualitative and quantitative description of the fish fauna composition of Lake Suviana (159 ha) and Lake Brasimone (53 ha), artificial basins in the Tuscan–Emilian Apennine mountain range, over 10 years, after the last emptying and filling operations were completed in 1975, samples were taken from each lake using professional fishing nets (Rossi et al., 1991); 390 kg and 169 kg of eel, respectively, were introduced in Suviana and in Brasimone during the period 1975–1987. Eel were not present in all samples, since they are not plentiful in these two lakes. In both Suviana and Brasimone, eel represent only 0.05% of total catches (mean Suviana total CPUE = 89.90, mean Brasimone total CPUE = 24.53). Using the data available from the sport fishermen also, the total catches per year were estimated. Every year in the Suviana lake from 15 to 29 kg of eel were fished, a yield of 0.1–0.34 kg ha^{-1}, while in Brasimone the observed range was from 5 to 18 kg per year, 0.1–0.2 kg ha^{-1}.

In some natural lakes, where professional fisheries are present, eel is the most important species and yields are increased by means of restocking. In the Lake of Garda, 368 km^2, northern Italy, eel have an important economic value for local fishermen, both professional and sport, since they represent the most constant target species (Ghetti et al., 1985). Eel presence is reported since 1816; restockings have been carried out on a regular basis since 1952. Fishing uses both trammel nets, fyke nets and different artisanal traps. Ghetti et al. reported data on annual eel yield since 1886.

Period	Total yield t	Yield t / ha
1887-1906	27.5	0.74
1920-1939	36.8	1
1952-1962	38.7	1.05
1974-1981	54.2	1.5

On the whole, besides fluctuations from year to year, an increase in production was evident from 1952 to 1981, related to restockings. Further increases were due to progressive increases in seeded quantities.

In other lakes of northern Italy, Lago Maggiore and Lago di Lugano, both shared with Switzerland (for the former, the Italian portion is 170 km^2, i.e. 80%, and for the Lago di Lugano, the Italian portion is only 18 km^2, 37%), data on fishing yield are available (Technical Commission for the Fishery in Italian-Swiss waters). For the Lugano lake the total eel fishing yield during 1986–1995 was 7.83 t, representing on average 1.6% of the total fish production. No catches were recorded in 1987, owing to the fact that fishing was forbidden in Swiss waters following the Chernobyl accident. The maximum catch was observed 2 years later, amounting to 5.07 t (Polli, 1996). For Lago Maggiore, the total eel fishing yield in the period 1979–1995 was 20.7 t, 1.2 t per year on average, representing about 0.3% of the total catch. The maximum, 2.3 t, was recorded in 1980 and the minimum, 0.3 t. in 1995 (Grimaldi, 1996).

Considering one of the small volcanic lakes of central Italy, an example of sustained stock is that of Bracciano Lake, in Latium, which has an area of 56 km^2 and a maximum depth of 160 m. Eel fisheries in the lake rely entirely on seeding practices carried out by the Rome Province Administration, as the lake is no longer connected to its effluent, the Arrone river (in which in the past glass eel recruitment was intense). Restocking practices began on a regular basis in the 1980s, small (20 g) eel being used. Quantities planted amounted to an average of 7 t each year (Moccia and Mattina, 1991). Fishing effort in the 15 years up to 1996 remained more or less constant, but yields fluctuated to some extent depending on factors such as the catchability of eel in winter. During colder periods, yields were low due to the fact that eel remain in the deeper parts of the lake. Average production can be estimated to range between 50 to 80 t in good years and 20 in bad years

It is evident from these case studies that lake production is low when compared to production in lagoon environments, ranging between 0.5 and 1.5 kg ha^{-1} with stockings amounting to about 46 glass eel ha^{-1} plus 0.05 kg ha^{-1} of bootlace eel, in the case of the Lake of Garda (Ghetti et al., 1985). Higher yields are obtained when restocking rates are higher, as in the Bracciano Lake, where an average 1.2 kg ha^{-1} of bootlace eel are stocked, yielding 4–14 kg ha^{-1} depending on years (Moccia and Mattina, 1991), but of course differences in environments must be taken into account.

Concerning the rivers, in the River Tiber, in the Latium region, entering the central Thyrrenian, a large eel population is present which is prevented from moving further upstream by a series of dams, the first of which is located about 40 km from the sea. Water quality is characterised by a high level of eutrophication, resulting from organic pollution due to a certain inadequacy of the civil waste treatment. Even if it has caused a reduction in the diversity of the macrobenthic community, this nevertheless sustains its quantitative abundance. This, together with the obstruction of the dam, has favoured a high eel population density.

Notwithstanding the fact that in the course of 20 years the fishing effort has improved, historical data series of glass eel catches have shown an overall decreasing trend, with catches dropping from >6 t per season in the period 1975–80 to about 4 t per season in the following 3 years. Minima were recorded in the years 1984–86 with a slight recovery in recruitment in the years 1987–1990. Thus, the typical abundance fluctuations from season to season were again confirmed. But in the years 1991–1996 the situation changed dramatically as no recovery was apparent. The glass eel yield was less than 200 kg in the season 1995–96. In spite of this, the yellow and silver eel yield has not shown a similar decline: average production continued to be of the order of 10–15 t per season, reasonably constant from year to year, even if fishing effort increased. Fluctuations in yield from season to season are mainly a function of the fishing days, which in their turn depend on the climatic conditions.

Historical records of stocking

Stockings are carried out frequently in Italy, but the significance of the stockings may be different from environment to environment. In lagoons, stockings are carried out in order to balance the fall in natural ascent, due both to environmental problems and to reduction of recruitment, but seedings are carried out methodically only in the valli of the northern Adriatic, where stocking is part of the management regime. As a rule, stockings are performed rarely with glass eel and more often with small eel (5–20 g).

In the valli di Comacchio, traditional fishery management has been carried out for centuries, but stocking has become the rule since the middle 1960s, when natural ascent became progressively reduced.

Official data of fish production have been available since 1781. The trend in those two centuries was characterised by fluctuations, but the average annual yield of fish per hectare is 16.4 kg, of which 14.3 kg are eel, about 78% of the total. Strong fluctuations can be observed in eel yield, ranging from 5 to > 30 kg ha^{-1}.

Fluctuations have always been due to environmental problems: a fall in 1822–1860 was due to hypersalinity and freezing of the valli, and to breaches in the Reno embankments. Around 1880 and in the 1925–1930 period falls in yield were also due to high mortality caused by cold and hypersalinity. Higher yields were obtained after 1964, coinciding with restocking and seeding practices while, from the late 1970s, yield has been considerably lower, 5–7 kg ha^{-1} because of a series of environmental problems, including filling and blocking of inlet canals, general decrease in recruitment, anoxic crisis due to phytoplankton blooms in consequence of increased pollution, cold winters (Ardizzone et al., 1988).

Rossi et al. (1987–1988), comparing yields in the 1980s and in the 1970s, attributed to the decrease in recruitment to the decrease in yield in the Comacchio lagoons. From 1979 to 1982 the natural recruitment of fry into the lagoons was limited by the fact that a regional law allowed direct fry fishing in the canals connecting sea and lagoons. During those years, therefore, recruitment was provided by artificial restockings with small yellow eel 1 year old, about 10 g, from the French Atlantic coasts in the following quantities :

Year	Restocking t
1978	16.3
1979	22.5
1980	34.4
1981	17.4
1982	13.5

The same authors calculated a yield per recruit of 58–113 g, but this value, using a mean value of 220 recruits ha^{-1}, would lead to a yield of 12.8–24.0 kg ha^{-1}. The observed yield in the period was, in reality, only 6 kg ha^{-1}.

From 1990, owing to the above-mentioned environmental problems and to internal problems of the Consorzio Valli di Comacchio, eel production has reached its historical minimum, falling to less than 5 kg ha^{-1}, stockings having been completely abandoned. Catches consist now only of large eel, the older individuals still inside the lagoon.

In most lakes, and in particular in the major Alpine lakes of northern Italy, eel stockings are performed to sustain fisheries, both professional and sport. In the Lake of Garda, where eel fisheries have been in operation since 1816, methodical restockings have been carried out since 1952, because natural ascent and eel migration have fallen as a consequence of the construction of dams along the effluent river. Both glass eel and small eel were used for restocking, until 1975 when restockings have been largely of small eel. The average quantity of seeded glass eel amounted to about 1,703,330 per year (510 kg), while average quantity of elver has been about 1.8 t per year, equivalent to an average of 46 glass eel and about 0.05 kg of small eel ha^{-1}. Yields ranged from 17.2 t in 1954 to 70.6 t in 1978: increase in yield in this period was due to progressive increases in seeded quantities (Ghetti et al., 1985).

The practice of restocking is quite widespread in inland waters, and it concerns most catchments and rivers. Periodically, restocking programmes adopted by the Fishery Commissions are subsequently carried out with eel bought from dealers or from aquaculture plants. In the past, wild glass eel were used together with small eel, but recently glass eel availability has been reduced and costs have increased; thus restockings use young eel in preference. In public waters, restockings are carried out at present by the local Administrations (Provincial or Regional), but often small lakes and river stretches are given in concession to Anglers Associations or to Co-operatives, that perform stockings, under the supervision of the Administration, aimed at enhancing the stocks for sport fishing. Even if those seedings concern mostly other fish species, eel are also restocked.

Vaudo et al. (1990) provide data on eel quantities used for restocking in the whole country for the period 1988–89. In 1988 12.7 t of glass eel and elver and 22.2 t of eel were used for these purposes for all Italy, while in 1989 11.23 t of glass eel and elver and 15.2 t of eel were used. In 1990 11.23 t of glass eel and 15.2 t of young eel were introduced in the Italian public waters (Melotti et al., 1990).

Data on population dynamics

Most studies on population dynamics concern northern Adriatic eel populations, and have been carried out between 1973 and 1983; no updated information is available in the literature.

Rossi (1979) examined 276 yellow and 552 silver eel caught in the Valli of Comacchio during 1974–76, and determined the survival and growth curve. M value was 0.72 for males and 0.34 for females. M values have been calculated on the Comacchio population 10 years later; their value was then 0.57 for males and 0.25 for females. Growth curves have also been calculated for the Monaci lagoon (Ardizzone and Corsi, 1985) and for the lower Tiber (AAVV, 1987).

Length attained by eel in North Adriatic lagoons is high: the observed range was 30.6–54 cm for males and 30.1–100 cm for females (means respectively 43.2 and 59.6 cm) in the Valli of Comacchio; maximum age observed was 9 years for males and 14 for females (Rossi, 1979; Rossi and Colombo, 1979). Sex ratio in the Comacchio lagoon is strongly skewed in favour of females: 79.4% (Rossi, 1979), 88.14% (Rossi and Colombo, 1979). It is interesting to observe that Rossi et al. (1987–1988) compared the silver eel population in Comacchio in the 1970s and 1980s and found no differences in growth but differences in sex ratio, 9:1 in favour of females; they attributed this to the strong decrease in density that occurred in this 10 year period. In other north Adriatic valli, Rossi et al found sex ratios always in favour of females (80–95%).

A completely reversed situation seems to be present in the southern North Adriatic coastal lagoons, where sex ratios seem always in favour of the males: 20% females in the Lagoon of Lesina, 10% females in the Lagoon of Varano (Rossi and Villani, 1980) and as low as 3% in the Acquatina coastal lake (Rossi and Corbari, 1982). In these lagoons eel residence inside the lagoon seems to be shorter than in the North Adriatic: maximum observed age was 6+ in Lesina for both males and females, 7+ for males and 5+ for females in the Varano Lagoon (Rossi and Villani, 1980) and 8+ in the Acquatina coastal lake (Rossi and Corbari, 1982). An intermediate situation has been observed in Porto Pino, Sardinia, where 60% females have been observed, and a maximum age for silver eel of both sexes of 9^+ (Rossi and Cannas, 1984).

The life cycle of *Anguilla anguilla* presents several distinctive features, such as high plasticity in body growth, marked sexual dimorphism, sex ratio strongly skewed in favour of the female and sexual maturation largely dependent upon the size of individuals. A demographic model incorporating all these characteristics was derived using 1989 population data from Comacchio lagoons and an estimate was made of survival at different ages. Survivorship in the juvenile stage (35% from age 1 to age 2) is much less than that in the older age-classes for which it is roughly 90%. An estimate was made also of the metamorphosis rate and abundance in each age- and size- class for both yellow and silver eel, crucial information for the management of the Comacchio fishery. The use of a non-parametric technique (bootstrapping) yielded not only the moments, but also the distribution of the estimates. Validation of the model was performed on data collected in 1990. The approach adopted was very flexible, and different assumptions about survival, sexual maturation and net selectivity could be easily incorporated in the model (De Leo and Gatto, 1995).

No data are available for lake populations, while population dynamics in the river Tiber have been studied (AAVV, 1987). In this river a sex ratio strongly in favour of the males was observed both for yellow (78.6%) and silver eel (64.6%), with a maximum observed length of 36.9 cm for silver males and 47.4 cm for silver females. It is interesting to note that a reduced residence in the river can be inferred, as eel > 5+ have not been found.

Recruitment

Natural mortality of glass eel

No information.

Fishing mortality of glass eel

Fishing pressure in those estuaries where glass eel fisheries are carried out is supposed to be very strong, as in the Tiber river. For the River Tiber eel population, a study of population dynamics has been performed by analytical models, using Von Bertalanffy data of the male fraction of the population, which is strongly dominant. Numbers of individuals for each age class and fishing mortalities for each age class have been evaluated by VPA using catches for each age class and assuming mortalities M=1.0 for glass eel and M=0.8 for the 1+ to 5+ age classes (AAVV, 1987).

Data on survival of glass eel or bootlace eel after stocking

Estimates of natural mortality of glass eel have never been performed using mark–recapture methods in coastal lagoon environments nor in estuaries. Gatto et al. (1982) set up a mathematical model for the population dynamics of eel in the Valli di Comacchio, using samples from the 1974–1976 catches. The model is based on a series of considerations, one of which is that the natural mortality can roughly be divided into a juvenile mortality up to age 2+, and an adult mortality. For the former, a survival value of 0.398 (survival rate 40%) has been evaluated by the authors.

Rossi and Papas (1979) provide data on the Valle Nuova, a complex of three valli of about 1,900 ha, during the period 1950–1978. Each year the seeded quantities have been about 2.2 kg per hectare, using small eel of about 20 g. The authors in this environment have calculated a survival rate for the eel, proportional to its size at seeding, ranging between 34% when small eel (5 g) are seeded and 2% when glass eel are used. Between 1950 and 1978, eel represented about 47% of the total production which ranged between 10 and 30 kg ha^{-1} from 1950 to 1958, rising to about 50 kg ha^{-1} till 1965, and falling in the period 1965–1978 for two reasons: the flooding that struck the whole region in 1966, destroying all the enclosing embankments, and the spreading of the parasite *Argulus giordanii*, that affected the whole Italian extensive eel production in the 1970s.

Data on economics of stockings

No information is available in the literature on the economics of stocking. It would in any case be difficult to calculate the economic return of stocking, in view of the different stocking regimes, whether glass eel or small eel (5–20 g) are used, and the different purposes of the stockings, which may be:

- in coastal lagoon environments to sustain and increase yields

- in rivers, to enhance stocks, and to counteract the presence of impassable dams, and to sustain mainly sport fisheries

- in lakes and reservoirs to enhance eel stock and to sustain fisheries

- as seed in intensive aquaculture

Escapement

Escapement of glass eel

No data available. Glass eel escapement rate is supposed to be extremely reduced, owing to the fishing pressure in many estuaries. Where fishing pressure is not too high, escapement towards higher regions is frequently reduced by dams.

Escapement of silver eel

No information available. Escapement of silver eel can, however, be considered as minimal not only in lakes, but also in most coastal lagoons, owing to the presence of fish barriers where silver eel are caught during their migration towards the sea. Escapement is extremely reduced in those estuaries, such as the Tiber, where eel fisheries are present.

Number and extent of unexploited water bodies

No information available.

Information on conservation measures

In Italy there are no measures specifically aimed at eel stock conservation, other than the prohibition of glass eel commercialisation for human consumption. Destination of glass eel ought to be, in fact, only seeding for aquaculture or restocking of natural basins. Notwithstanding the fact that direct consumption is forbidden, a certain amount of glass eel for consumption reaches the traditional markets of Pisa, Livorno, Viareggio, Lucca (Ingle, 1988; Rossi and Franzoi, 1991). The existence of this black market is due to three main causes: besides a higher profit for the fishermen, there is a reduced interest from aquaculture installations (both intensive and extensive) in wild glass eel as seed, because of the reduced survival rates; weaned elver or small eel (6–20 g) from France are preferred.

With regard to fisheries regulation, for glass eel fisheries in coastal waters and estuaries (within the limit of salt and brackish waters) authorisation by the Ministry of Agricultural, Food and Forest Resources is necessary, to be renewed yearly. Each licensed fisherman or co-operative, when applying for authorisation for fry fishing, must declare catches of the previous year, the quantities to be caught, the areas where the fishing activity will take place and the destination of the fry (aquaculture, restocking, etc.). No restrictions on fishing season nor on gear are indicated by the Ministry for glass eel fishing, contrary to other finfish and bivalve fry, except for the fact that glass eel fishing is forbidden from 15 July to 15 September. The authorisation is valid in the whole national territory, while in Sardinia and Sicily fry fishing is forbidden by regional laws.

In inland waters eel fishing is regulated by the Provincial Administrations or the Regions. Usually an individual professional fishing licence is issued (type A), valid for 6 years and only within the Region. Each Province keeps registers where all fishing licences, professional or for angling, are listed. For the eel, a size limit is established (25 cm), while there are no limits with regard to season. With regard to eurhyhaline fry fisheries, and therefore to glass eel, the Regions (except Sardinia and Sicily) tend to act in agreement with the Ministry of Agriculture, Food and Forest Resources and with the adjoining Provinces: thus, professional fishermen who intend to operate fry fisheries in inland waters (above the limit of brackish waters) have to ask for a special authorisation from the Regional Committee, stating periods, places, fish species, equipment for fishing and fry transportation. Fishermen must also declare sales of fry, and destination (aquaculture, restocking); the Province Administrations can demand a certain quota of the catches for restocking purposes.

References

AAVV (1987) *Studio della popolazione di anguille del basso corso del fiume Tevere e considerazioni sulla pesca.* Rapporto, Amm. ne Provinciale di Roma.

AAVV (1988) *ATTI: Seminari delle unità operative responsabili dei progetti di ricerca promossi nell'ambito dello schema preliminare di piano per la pesca el'acquacoltura.* Ministero della Marina Mercantile/ CNR, Natural fish fry session, Vol. II: pp 709–1013.

Ardizzone G.D. and Corsi F. (1985) Eel population structure, dynamics and fishing yield in a Mediterranean coastal lagoon. *Oebalia* 11 NS, 547–560.

Ardizzone G.D., Cataudella S. and Rossi R. (1988) Management of coastal lagoon fisheries and aquaculture in Italy. *FAO Fisheries Technical Paper* 293, 103 pp.

De Angelis R. (1961) Production des Poissons dans les eaux intérieures Italiennes. *Proceedings General Fisheries Council for the Mediterranean*, 6, 229–232.

De Angelis R. (1986) Italy. *EIFAC Occasional Paper* 16, 83–88.

De Leo G.A. and Gatto M. (1995) A size and age-structured model of the European eel (*Anguilla anguilla* L.). *Canadian Journal of Fisheries and Aquatic Sciences*, 52, 1351–1367.

Dill W.A. (1990) Inland fisheries of Europe. *EIFAC Technical Paper* 52, 242–272.

Gatto M., Laniado E. and Rossi R. (1982) The management of eel in the valli di Comacchio lagoon. *Oceanologica Acta*, n° sp, 303–307.

Ghetti P.F., Oppi E. and Gandolfi G. (1985) *Aspetti della Vita delle anguille nel Lago di Garda (Missione Piccard, settembre (1981).* Civiltà gardesana, studi ed esperienze, 3., L'ambiente lago, 1985, 111–125.

Grimaldi E. (1996) *Rapporto informativo sul pescato professionale nel Lago Maggiore per il 1995.* Commissariato italiano per la pesca nelle acque italo-svizzere, Verbania Pallanza, 8 pp.

Ingle E. (1988) Allevamento larvale di pesci marini: realtà e problematiche per lo sviluppo del settore. *Il Pesce*, 4/88, 31–34.

Istituto Nazionale di Statistica (1996) *Staitstiche della Caccia e della Pesca. Sistema Statistico Nazionale.*

Melotti P., Regazzi D., Roncarati A., Sirotti C. and Trincanato A. (1990) *Indagine sullo stato dell'acquacoltura nelle acque interne. Ed.* API (Associazione Piscicultori Italiani), 91 pp.

Moccia G. and Mattina F. (1991) La gestione della pesca dell'anguilla nella provincia di Roma. *Bollettino dell'Accademia Italiana dell'Anguilla*, Anno 1, 2, 11–16.

Polli B. (1996) *Rapporto informativo sulla Pesca nel Lago di Lugano.* Sottocommissione tecnica della Commissione italo-svizzera per la pesca, Bellinzona, maggio 1996.

Rossi R. (1979) An estimate of the production of the eel population in the Valli of Comacchio (Po Delta) during 1974–1976. *Bolletino di Zoologia*, 46, 217–223.

Rossi R. and Cannas A. (1984) Eel fishing management in a hypersaline lagoon of southern Sardinia. *Fisheries Research* 2, 285–298.

Rossi R. and Colombo G. (1976) Sex ratio, age and growth of silver eel in two brackish lagoons in the northern Adriatic Valli of Comacchio and Valle Nuova. *Archivi di Oceanografia e Limnologia*, 18, suppl. 3, 327–341.

Rossi R. and Colombo G. (1979) Some observations on age, sex and growth of silver eel (*Anguilla anguilla* L.) in North Adriatic lagoons. *Rapports et Procès verbaux du Conseil internationale pour l'Exploration de Mer* 174, 64–69.

Rossi R. and Corbari L. (1982) La fauna itticadei laghi Suviana e Brasimone (bacini artificiali dell'Appenino Tosco-Emiliano. *Rivista di Idrobiologia,* 30, 1, 157–177.

Rossi R. and Franzoi P. (1991) Pesca di ceche lungo le coste italiane nel periodo 1987–89. *Bollettino dell'Accademia Italiana dell'Anguilla (AIDA):* Anno 1, 1: 5–17.

Rossi R. and Papas P. (1979) Analisi del pescato di una "valle" del Delta del Po (Valle Nuova, Ferrara) dal 1950 al 1978. *Annali del Università di Ferrara* (Biologia, I), 9, 123–148.

Rossi R. and Villani P. (1980) A biological analysis of eel catches, *Anguilla anguilla,* from the lagoons of Lesina and Varano, Italy. *Journal of Fish Biology* 16, 413–423.

Rossi R., Carrieri A., Franzoi P., Cavallini G. and Gnes A. (1987–1988) A study of eel (*Anguilla anguilla*) population dynamics in the Comacchio lagoons (Italy) by mark-recapture method. *Oebalia* 14, NS, 1–14.

Rossi R., Carrieri A. and Rizzo M.G., (1991) Fish fauna in the Suviana and Brasimone lakes (artificial basins in the Tuscan-Emilian Apennine mountain range). *Rivista di Idrobiologia* 30, 157–177.

Vaudo A., Scaglia R. and Bronzi P. (1990) Il contributo dell'anguilla al mercato del pesce di acqua dolce in Italia: approccio conoscitivo. *Bollettino dell'Accademia Italiana dell'Anguilla,* numero unico.

ANNEX 2. HABITAT, STOCK AND YIELD (ACTUAL AND POTENTIAL) AND ESTIMATED ESCAPEMENT OF EXPLOITED SILVER EEL

This annex provides details from the country reports of habitats, recruitment, known yield and potential yield together with estimates of spawner escapement from exploited waters.

The sources of information are listed in the tables as a reference code. These link to the literature cited on page 40 above.

A.2.1 Habitat

The country reports provide an estimate of the total surface area of outdoor waters in each country and, where available, an estimate of the percentage that is accessible to eel. In cases where river lengths were given instead of surface area, an average width of 10 m was assumed. In summarising the country reports, waters were classified under one of the following headings:

-*Fresh still waters:* all water bodies characterised by a low salinity, where the standing stock is largely dependent on biological production within the same water body. This includes lakes, reservoirs, canals, polders, extensive aquaculture ponds.

-*Fresh running waters:* all water bodies characterised by a low salinity, where the stock is at least partially dependent on biological production in connected, mostly upstream areas. This conforms almost exclusively to rivers and streams.

-*Saline, closed waters:* all water bodies characterised by a relatively high salinity but with limited interchange with the open sea, where the standing stock is largely dependent on biological production within the same water body. This includes coastal lagoons and some fjords.

-*Saline, open waters:* all water bodies characterised by a high salinity, where the stock is at least partially dependent on biological production in connected areas. This includes estuaries, river mouths, open coastal areas, archipelagos.

-*The Baltic area* is difficult to classify within the above system. Since it represents as much as 18% of the hbaitat of the eel, it is treated on its own..

The percentages of surface area inaccessible to eel were taken directly from the country reports.

A.2.2 Glass eel

Current stocking rates of glass eel are variable, with a maximum of 0.5 kg ha^{-1}. The number of studies on optimal levels of stocking is low. An overall base level for potential stocking of glass eel of 0.1 kg ha^{-1} was assumed, unless specific information was available for particular regions. In open systems, stockings might not contribute to the local production. In most inland waters, however, the stocking of rivers would benefit individual countries.

Natural recruitment to open coastal waters, including estuaries, is an unknown quantity but likely to be higher than to closed and inland waters. The relatively enormous areas involved would require unattainably large quantities of stocking material and it was considered unlikely that serious attempts would be made to undertake such a programme in the foreseeable future. A notional figure of 0.01 kg ha^{-1} was included in the table.

Figures for actual stocking levels, as well as estimates of natural recruitment were taken from the country reports. In several cases, waters are stocked using bootlace eel. These quantities were transformed to the equivalent amount of glass eel. The contrast between actual stockings and the minimal potential derived from the base level as defined above, is listed as 'estimated understocking'. Lack of knowledge on natural immigration results in a high estimate of understocking.

In the case of France, the natural immigration of glass eel is estimated at 60 t, while the minimal level required comes to only 8 t. Consequently, the estimate of understocking appears as a negative figure, the actual immigration level (after fisheries) exceeding the continent-wide base level for stocking. However, there are serious doubts as to the optimal level of stocking in France, but there are no published sources to justify the use of a higher estimate.

A.2.3 Yellow and silver eel

The potential yield in European waters was estimated, on the assumption that seed stocking and local management might be optimised by proper stock-wide management. In this respect, a strategy parallel to the one on glass eel stocking was used: a continent wide base level, with specific values in cases where local evidence is available. Unlike the case of glass eel stockings, the base level was determined by type of water body: 10 kg ha^{-1} yield for all fresh waters, 20 kg ha^{-1} for saline closed systems and 5 kg ha^{-1} for saline, open systems. The yield in the Baltic was estimated at 5 kg ha^{-1}, because of the negative influence of low temperatures and short growth seasons.

Figures for actual yields of yellow and silver eel were taken from the country reports. The contrast between the estimated potential yield and the reported catches makes up the estimate of underexploitation. This latter quantity indicates the yield that could be attained by proper local management and the provision of adequate seed stocking levels, rather than the yield available simply by increasing the level of exploitation of existing stocks.

Several entries indicate a higher actual yield than the assumed potential. This can arise where actual recruitment is greater than the proposed overall stocking rate of 0.1 kg ha^{-1}.

A.2.4 Silver eel

The quantity of silver eel escaping is unknown, but an estimate was derived from the known catches of silver eel, on the assumption that at least 10% of the original stock is able to escape the fisheries. Wherever a detailed assessment of the escape rate was available, the best estimate was used. In all cases, these best estimates were in the order of magnitude of 30%, indicating the conservatism in the overall value of 10%.

Annex 2. Table 1. Habitat, stock, yield and escapement

Country	Habitat	Surface area a			Stocking b	c	d		Yellow and silver eel	e		Silver eel		
		Accessible (km^2)	Obstructed artificially %	Obstructed naturally %	Rate (kg/ha)	Natural recruitment (t)	Stocking (t)	Understocking (a*b/10)-(c+d)	Assumed yield (kg/ha)	Estimated yield	Under-exploitation (a*i/10)-e	Known yield	Escape rate %	Minimum escapement
Baltic	Sweden	14,435		43	0.10			144	5	586	6,631	557	30	239
	Denmark	900			0.10			9	5	419	31	425	30	182
	Germany	700			0.10			7	5	320	30	96	30	41
Swden	Fresh still	17,838		55	0.10	1	2	176	10	460	17,378	117	10	12
	Fresh running	277		65	0.10			3	10					
	Saline closed	8,600			0.10		1	86	10	430	8,170		30	
	Saline open				0.01					199	-199			
Denmark	Fresh still	440			0.10			4	10	110	330			
	Fresh running	150	10		0.10			1	20	20	280			
	Saline closed	3,000			0.10		2	28	10	405	2,595	200	10	22
	Saline open	9,100			0.01			9	2	405	1,415			
Germany	Fresh still	230	20	5	0.10		2		10	400	-170			
	Fresh running	600	20	5	0.10		1	5	10	275	325	250	10	28
	Saline closed	1,600			0.10			16	10	200	1,400	100	10	11
	Saline open				0.01									
N. Ireland	Fresh still	626	5		0.10	1	1	4	15	735	204			
	Fresh running	20			0.10				10		20			
	Saline closed				0.10									
	Saline open	21			0.01				5		11			
Rep. Ireland	Fresh still	1,445		5	0.10		2	12	10	250	1,195			
	Fresh running	53		5	0.10			1	10		53			
	Saline closed	5			0.10				20		10			
	Saline open	600			0.01			1	5		300			
Great Britain	Fresh still	1,924			0.10			19	10	300	1,624			
	Fresh running	500			0.10			5	10		500			
	Saline closed				0.10				20					
	Saline open	5,000			0.01			5	2	50	950			
Netherlands	Fresh still	3,400	5		0.10	5	12	17	10	685	2,715	14	10	2
	Fresh running	100			0.10			1	10	20	80			
	Saline closed	1,950			0.10			20	10	100	1,850			
	Saline open	5,000			0.01			5	1	100	400			
France	Fresh still	1,696	5	5	0.10			17	10		1,696			
	Fresh running	840	10		0.10	60		-52	10	300	540			
	Saline closed	590			0.10			6	40	300	2,060			
	Saline open	1,000			0.01			1	5		500			
Portugal	Fresh still	3	99		0.10				10		3			
	Fresh running	18	70		0.10				10		18			
	Saline closed	50			0.10			1	20	67	33			
	Saline open	325			0.10				5	33	130			
Spain	Fresh still	10			0.10				10		10			
	Fresh running	50	93		0.10			1	10	400	50			
	Saline closed	171			0.10			2	20	100	242			
	Saline open				0.10				5	75	-75			
Italy	Fresh still	2,360	59		0.10		6	18	5	400	780			
	Fresh running	108	50		0.10		4	-3	10	100	8			
	Saline closed	1,500			0.50			75	40	1,400	4,600			
	Saline open				0.10				5					
Sum or average	Fresh still	29,971	4	40	0.10	7	25	268	10	3,340	25,764	301	12	71
	Fresh running	2,717	25	13	0.10	60	5	-38	11	715	2,152	250	10	28
	Saline closed	17,466			0.14		3	232	14	3,002	20,960	300	12	33
	Saline open	21,046			0.10			21	2	862	3,431			
	Baltic	16135		40	0.10			161	5	1,325	6,743	1,078	30	462
Total		**87,335**	**3**	**27**	**0.10**	**67**	**33**	**644**		**9,244**	**59,050**	**1,929**	**12**	**595**

ANNEX 3. POPULATION PARAMETERS IN THE LITERATURE

In this annex, data on population parameters available in the literature and the country reports (Annex 1 of this report) are summarised in four tables. The habitats of eel were classified in one of four classes, as was done in Annex 2 of this report: running fresh waters, still fresh waters, open saline waters and closed saline waters (see Annex 2). Population parameters on production and yield, and on natural and fisheries mortalities are listed.

Anex 3. Table 1 Still fresh waters

	Habitat	Production kg/ha	Yield kg/ha	Yield g/recruit	Natural %	Natural Z	Fishing %	Fishing F	Comment	Reference
Sweden	18 Lakes		0.1 -3.4						18 Lakes	53
	Lake		1.24		<26				Productive lake stocked	54
Finland	Various lakes			10-72 -90	73				Stocked lakes	40
	Small lake				28				Rotenoned	40
Germany	L Constance		3 - 6						Stock glass	3
Poland	Various Lakes		2.4	19					Stocked	18
	Gt Mazurian Lakes		4.3	63					Stocked	19
	454 Lakes		2.8	15.5					Stocking vendace Lakes	20
	454 Lakes		3.2	22					Stocking pikeperch lakes	20
	86 lakes		5.2	19					Stocking	31
	(estimation*)		4.6	85.5*					Various lakes inc.	16
N. Ireland	L Neagh		16.1Y	49			75		Y = yellow	55,16
	L Neagh		17	105						41
	L Erne			19						33
	L Erne			40						41
Rep. Ireland	Shannon lakes	4.2	0.7Y	5			20		Low Exploitation	25,28,30
	L Corrib		0.9Y							29
	L Derg		<2	7.6						27
	L. Ree & L. Derg				68-74	0.3-0.38				26
Netherlands	IJsselmeer		5Y					0.5		9
	Ponds		6 - 8						Stocking Glass eels	15
	Ponds		10.6		30				1+ eels	15
General	Stocked warm		20	40-50	75	0.17-0.65				

Annex 3. Table 2. Running fresh waters

	Habitat	Density N/100 m^2	Density kg/ha	Production kg/ha/	Yield kg/ha	Yield g/recruit	Mortality %	Mortality Z	Mortality F	Comment	Reference
Norway	Imsa	1.2	10.2			115.6	73				51
	Imsa				1.9						13
Sweden	Broalven			4.3						Of 0 - 1+ eels west coast	49
	12 streams	1.7 - 6.3									8
Denmark	Streams	21 - 1300	163	9 - 93				0.23 - 1.79			38
	Streams		75								16
	Gudena						77- 82			100 days post stocking	4
	Streams						96.70			stocked	38
	Streams						59.90			wild	38
	Granslev	5	10	5							34
Poland	Pilica		0.46	0.004							24
Rep. Ireland	Nore	5	52 - 70							Rotenone short stretch	32
	Dunkellin	3 - 134									5
	Burrishoole				1.1						39
Great Britain	Severn	0.6 - 113.9		0 - 6.52						Estuary tributaries	1
	Severn	0 - 4		0 - 6.52						Lower tributaries	1
	Thames	6	0 - 3.0							Lower tributaries	35/36
	Thames	0 - 0.2	1-12							Other tributaries	35/36
	East England	0.5 - 50	35 - 210				25				2
	Tweed	13 - 93	36 - 328								12
	181 Upland	3 - 8	1.66 -							pH <5.1 - >6.5	50
	Rivers	3-									22
	Rivers	44 - 430									22
	Tadnoll	50	10	3.12							23
	Frome	5 - 200									14
France	Nivelle		108								37
	Rivers	5	40	0.9 - 8						Brittany	10
	Rivers		60							Normandy	10
Portugal	Tejo	90	227							Creek below dam	7
Spain	Chabatches	30 - 38									21
Italy	Tiber								0.8		6
General	Rivers	0.1 - 3	3 - 100		High 20 - 50,						48
	Rivers	7.8	6.36								22

Annex 3. Table 3. Lagoons (saline, closed)

	Habitat	Density N/100 m^2	Density kg/ha	Production kg/ha/y	Yield kg/ha	Yield g/recruit	Mortality	Comment	Reference
France	Coastal lagoons	600 - 2000	70 -> 20		99 -> 45			Reduced habitat & water quality, Mediterranean coast	10
	Creeks and lagoons		100 - 500		30 - 100			Man made salt marshes & pans, Atlantic coast.	10
Italy	7 N. Adriatic Lagoons		76	36	19			falling recruitment since 1970s	45
	Comacchio			13 - 27	29	58 - 113		pre 1980	47
	Comacchio				5 - 7			post 1980	6
	Valle Nuova				5 - 25			1950 - 1978	46
	Aquatina				4.6 - 17.6			1976 - 1979	44
	Porto Pino				19	12			43
	Tortoli Lagoon				120 - 130			1957 - 64	6
	Tortoli Lagoon				40			1965 - 1978	6
	Lesina				7 - 36			1950 - 70	6
	Other				6 -324	12	40% @ 2+ 10-23% @ >2+		6

Annex 3. Table 4. Estuaries (saline, open)

	Habitat	Productio kg/ha	Mortality Natural %	Mortality Natural Z	Mortality Fishing %	Comment	Reference
Sweden	Broalven Estuary	0.06 -0.69				0+ to 1+ eels	49
	coastal			0.18	27		53
	coastal		80			1 year	52
England	Thames estuary			0.37		Estimate (per cm year class)	35/36
Italy	Po Delta	36					42

Reference list for Annex 3. Full citations are given on p 39.

1 Aprahamian, 1988
2 Barak and Mason, 1992
3 Berg, 1988 (cited in 11)
4 Berg and Jorgensen, 1994
5 Callaghan and McCarthy, 1991
6 Cicotti, 1997
7 Costa et al., 1991
8 Degerman et al., 1986
9 Dekker, 1997
10 Fontenelle, Feunteun & Briand, 1997
11 Hahlbeck and Kuhlmann, 1997
12 Hussein, 1981
13 Hvidsten, 1985
14 Ibbotson et al., 1994
15 Klein Breteler, 1994
16 Knights and White, 1997a
17 Larsen, 1955 (cited in 31)
18 Leopold, 1980
19 Leopold, 1986
20 Leopold and Bninska, 1984
21 Lobon-Cervia et al., 1990
22 Mann, 1995
23 Mann and Blackburn, 1991
24 Mann and Penzak, 1994
25 McCarthy et al., 1994a
26 McCarthy et al., 1994b
27 Moriarty, & Reynolds
28 Moriarty, 1987
29 Moriarty, 1990b
30 Moriarty, 1990c
31 Moriarty et al., 1990
32 Moriarty and Nixon, 1990
33 Moriarty and Tesch, 1997
34 Mortensen, 1982
35 Naismith and Knights, 1990b
36 Naismith and Knights, 1993
37 Neveu, 1981
38 Pedersen,
39 Poole et al., 1990
40 Pursainen and Toivenen, 1984
41 Rosell, 1997
42 Rossi, 1979
43 Rossi and Cannas, 1984
44 Rossi and Corbari, 1982
45 Rossi and Colombo, 1976
46 Rossi and Papas, 1979
47 Rossi et al., 1987 – 1988
48 Tesch, 1977
49 Thorman and Fladvad, 1981 (Cited in 54)
50 Turnpenny, 1989
51 Vollestad and Johnsson, 1988
52 Westerberg et al., 1993
53 Wickström and Hamrin, 1997
54 Wickström et al., 1996
55 Winfield et al., 1993

ANNEX 4. OBSERVATIONS ON THE GLASS EEL FISHERY IN 1997

Guy Fontenelle
Laboratoire Halieutique, ENSA, 65 Rue de St Brieuc 35042,

This account is based on information from an established eel merchant in February 1997.

Glass eel are collected along the coast by commercial (and non commercial) fishers in estuarine and lower parts of rivers. Then, they are mostly managed by to Basque traders who decide how to sort the glass eel depending on their potential. In large estuaries higher mortalities >10-20 % are frequent After cleaning, they separate dead from living and direct the dead to the Spanish market and the rest to China (Shanghai and Hong Kong) via Paris airport (50%), Amsterdam or London. At the arrival airport, a very small number of distributors take care of the glass-eel to distribute them among a large number of Chinese farmers. It seems impossible to get in touch directly with the farmers. This network appears very well controlled.

In mid-February 1997, the trading price for glass eel after holding in France was 1,860 F/kg and the price 'on arrival in Hong Kong' was about 2,300 F/kg for live fish. The price of dead fish used for consumption on the Spanish market was 300 F/kg. At t his period about 3 to per day were being shipped to China.

The glass eel are packed for shipping in foam plastic boxes of 12 litre capacity with 1 kg ice to every 1 kg glass eel.

On the Far-eastern fish farms, the high success may be explained by the high quality of natural food based upon *Tubifex*, prepared in the following way. Organic manure is placed in streams in which no other production is expected to induce *Tubifex* production. The worms are "purified" before being fed to the glass eel.

Table 1. Exports of glass eel from France in 1995 and 1996 (to end of August). From French Customs data through FIOM.

Destination	Quantity (t)	Value (KF)	Price F/kg
1995			
Hong Kong	50.4	34,855	692
China	7.7	4,468	580
UK	5.1	2,638	517
Greece	0.4	221	553
Indonesia	0.2	196	980
Lithuania	0.2	137	685
Total	64	42,515	Average: 668
1996			
Hong Kong	49	48,515	990
Denmark	12.4	4,200	339
China	11.8	12,887	1,092
UK	3.8	2,988	786
Japan	2.6	689	265
Germany	0.7	582	831
Mexico	0.5	231	462
Greece	0.4	361	903
Lithuania	0.4	518	1,295
Singapore	0.1	89	890
Taiwan	0.1	148	1,480
Total	81.8	71,208	Average: 870

A high survival rate of 90 % is achieved from glass-eel stage to 10-12 g. They can reach 3-5 g within 3-5 weeks. The grown eel are sold when they weigh more than 200 g which they can reach within only 10 months. They are exported mainly to Japan at about 60 F/kg for "kabayaki" product (about 80-92 F/kg). Recently, some distributors and farmers made requests to use estrogen hormones to induce female differentiation and therefore bigger eel.

The recent shift to the Asia market of glass eel from Europe seem likely to increase fishing effort as people are attracted by the high price offered. Although probably an incomplete figure, the export statistics from France (Table 1) indicate such a change (average price 870 F/kg in 1996 in contrast to 670 F/kg in 1995). In 1997, prices have increased much more.

According to the traders, about 80-100 tons had already left France on February 13, 1997. The Chinese market was estimated by the glass eel traders at about 110-120 tons in 1996, which means substantially more than the official export data. Today, there is no reliable information available to explain such a discrepancy and to track transnational shipping within the EU before Asian destinations are reached.

ANNEX 5. NAMES AND ADDRESSES OF PARTICIPANTS

Sweden

Stellan Hamrin	National Swedish Board of Fisheries, Institute of Freshwater Research, S-178 93 Drottningholm.
Hakan Wickström	National Swedish Board of Fisheries, Institute of Freshwater Research, S-178 93 Drottningholm.

Denmark

Michael Pedersen	Danish Institute for Fisheries Research, Inland Fisheries Laboratory, Vejlsøvej 39, DK-8600 Silkeborg,

Germany

Eka Hahlbeck	Bundesforschungsanstalt für Fischerei, Institut für Ostseefischerei, An der Jagerbäk 2, 18069 Rostock.
Holmer Kuhlmann	BFA-Fischerei, Inst. für Fischereiökologie, Wulfsdorfer Weg 204, 22926 Ahrensburg.

Ireland (Northern)

Robert Rosell	DANI, New Forge Lane, Belfast BT9 5PX.

Ireland (Republic)

Christopher Moriarty	Marine Institute, Fisheries Research Centre, Abbotstown, Dublin 15.
Julian Reynolds	Department of Zoology, Trinity College, Dublin 2.

Great Britain

Brian Knights	Applied Ecology Research Group, University of Westminster, 115 New Cavendish Street, London W1M 8JS.

Netherlands

Willem Dekker	RIVO-DLO, PO Box 68, 1970 AB IJmuiden.

France

Cédric Briand	Laboratoire Halieutique, ENSA, 65 Rue de St Brieuc 35042, Rennes Cedex.
Yves Desaunay	IFREMER, Centre de Nantes, Rue de l'Ile d'Yeu - BP 1105, 44311 Nantes Cedex 03.
Eric Feunteun	Université de Rennes, UMR CNRS 6533, Laboratoire ESNM, 35042 Rennes Cedex.
Guy Fontenelle	Laboratoire Halieutique, ENSA, 65 Rue de St Brieuc 35042, Rennes Cedex.
Raymonde Lecomte-Finiger	EPHE, Université de Perpignan, Avenue de Villeneuve, 66860 Perpignan Cedex.
Antoine Legault	Fish Pass, 85 Rue de St Brieuc, 3500 Rennes.

Portugal

Maria Assunção Santos	Instituto de Ciências Biomédicas de Abel Salazar , Universidade do Porto, Lg. Prof. Abel Salazar 2 , 4000 Porto.

Spain

María José Lara	C/. Cervantes No. 2, 2° Izda, 33206 Gijon-Asturias.

Italy

Eleonora Ciccotti	Laboratorio di Ecologia Sperimentale ed Acquacoltura, Università 'Tor Vergata', Via della Ricerca Scientifica, 00133 Rome.